THE ENGINEER SERIES

PAPER MAKING AND ITS MACHINERY

THE ENGINEER SERIES

PAPER MAKING AND ITS MACHINERY

INCLUDING CHAPTERS ON THE TUB
SIZING OF PAPER, THE COATING AND
FINISHING OF ART PAPER AND THE
COATING OF PHOTOGRAPHIC PAPER

BY

T. W. CHALMERS, B.Sc., A.M.I.Mech.E.

(On the Editorial Staff of "The Engineer")

AUTHOR OF

"THE PRODUCTION AND TREATMENT OF VEGETABLE OILS"

WITH SIX FOLDING PLATES AND
144 ILLUSTRATIONS IN THE TEXT

LONDON
CONSTABLE & COMPANY LTD
10 ORANGE STREET LEICESTER SQUARE WC 2
1920

Printed in Great Britain.

PREFACE

In spite of the fact that practically at every point the modern papermaking industry is dependent in a very essential degree upon the art of the engineer, the English technical literature dealing with the industry is distinctly deficient in its treatment of the matter from the engineering point of view. The chemist interested in papermaking is amply served in the way of technical literature, but the engineer, upon whom, without egotism, we may claim at least as much responsibility falls as upon the chemist, has hitherto been almost wholly unprovided with anything in the shape of a general treatise upon the industry written from his own point of view and for his especial benefit.

No doubt a desire for secrecy on the part of the manufacturers of papermaking machinery may be set down as one of the chief reasons for the existence of this state of affairs. However it may be, the fact remains that in the earlier period of the war, *The Engineer*, on the editorial staff of which the author has the honour and pleasure of serving, succeeded in persuading most of the leading British paper machinery makers to place at its readers' disposal a great deal of valuable information and numerous drawings and other illustrations representing their established and current practice. The outcome was a series of articles—" Paper Making and its Machinery " —which appeared in *The Engineer* between the dates October 1st and December 31st, 1915. Subsequently that series was rounded off and rendered more complete by five articles devoted to " The Art of Coating Paper "—August 25th to September 29th, 1916—in which information was given concerning the coating of art paper, a highly important part of the papermaker's work, and the cognate subject, the coating of photographic paper. It may perhaps be remarked here that this was the first occasion upon which information concerning the methods employed in the commercial coating of photographic paper had been published anywhere, and that as regards the coating of art paper the particulars given of the methods and machinery used were much fuller than those previously available. In the chapters that follow these two series of articles are combined to form what it is hoped will be found by paper machinery makers and users a satisfactory and substantially complete account of the engineering aspects of the modern papermaking industry.

A large measure of thanks is due to all those firms who supplied the information and illustrations upon which the two series were founded, and to the proprietors and managers of the *Daily Telegraph* and other mills who afforded opportunities for the author to study many of the actual machines described in the text, under working conditions.

T. W. C.

London, October, 1919.

CONTENTS

CHAPTER I

PAGE

INTRODUCTORY 1

CHAPTER II

CUTTING, CLEANING, AND BOILING 6

CHAPTER III

WASHING, BREAKING, AND BLEACHING 15

CHAPTER IV

PURIFYING AND PULPING 24

CHAPTER V

BEATING 36

CHAPTER VI

REFINING 46

CHAPTER VII

THE FOURDRINIER MACHINE 55

CHAPTER VIII

FOURDRINIER DRIVING ARRANGEMENTS 69

CHAPTER IX

DETAILS OF THE FOURDRINIER 78

CHAPTER X

DETAILS OF THE FOURDRINIER—*continued* 87

CHAPTER XI

PULP STRAINERS 97

CHAPTER XII

TUB SIZING 109

CHAPTER XIII

CALENDERING, CUTTING, AND WINDING 118

CHAPTER XIV

WOOD PULP 133

CHAPTER XV

PAGE

The Coating of Art Paper 144

CHAPTER XVI

The Coating of Art Paper—*continued* 151

CHAPTER XVII

The Finishing of Coated Art Paper 157

CHAPTER XVIII

The Coating of Photographic Paper 162

CHAPTER XIX

The Coating of Photographic Paper—*continued* 166

Index 175

LIST OF ILLUSTRATIONS

FIG.		PAGE
1.	Bertrams' Rag Chopper	7
2.	Bertrams' Rag Chopper	7
3.	Nuttall's Rag Cutter	8
4.	James Bertram's Straw Chopper	8
5.	Bertrams' Willow and Duster	9
6.	Bertrams' Willow and Duster	9
7.	Bertrams' Double Drummed Willow	10
8.	Bertrams' Conical Grass Duster	10
9.	Bertrams' Conical Grass Duster	11
10.	Bertrams' Revolving Cylindrical Boiler	12
11.	James Bertram's Esparto Boiler	13
12.	Bertrams' Esparto Boiler	14
13.	Diagram of a Hollander	16
14.	James Bertram's Grass Breaking and Washing Engine	17
15.	Rag Breaking and Washing Engine	18
16.	Cornett's Mixing and Bleaching Engine	19
17.	Cornett's Cone Breaker—James Bertram	20
18.	The Bleaching Tower System—Masson, Scott and Co.	21
19.	Bleach Mixers	22
20.	Presse Pâte—Bertrams'	25
21.	Couper Concentrator—Masson, Scott	26
22.	Kollergang—James Milne and Son	28
23.	Kollergang—James Milne and Son	28
24.	"Perfect" Pulper—Masson, Scott	29
25.	"Perfect" Pulper—Masson, Scott	29
26.	"Watford" Pulper—Watford Engineering Works	30
27.	Power Consumption of "Watford" Pulper	31
28.	"Partington" Disintegrator—Glossop Ironworks	32
29.	"Partington" Disintegrator	33
30.	Kneader—Bertrams'	34
31.	Kneader, Inside—Bertrams'	35
32.	Hollander Beating Engine—James Bertram	36
33.	Umpherston Beater	37
34.	Hollander Beater with Hydraulic Plates	38
35.	Umpherston Beater with Hydraulic Plates	39
36.	Tower Beater—Masson, Scott	41
37.	Reed Beater—Milne	42
38.	Attachment of Blades to Roll	42
39.	Bertrams' "Acme" Beater	43
40.	"Acme" Beater with Washing Drum	44
41.	Nash's Beater—Milne	45
42.	Hollander Power Diagram	47
43.	Conical Refiner—Masson, Scott	48
44.	Casing of Conical Refiner	48
45.	Rotor of Conical Refiner	49
46.	Milne's Refining Engine—Bertrams'	50

LIST OF ILLUSTRATIONS

FIG. PAGE
47. Milne's Refining Engine—Bertrams' 50
48. Milne Refiner with Concentrator 51
49. Kingsland Refiner 52
50. Kingsland Refiner—Glossop Ironworks 53
51. Diagram of a Fourdrinier Papermaking Machine 56
52. White's Driving Gear 57
—. 102-in. Papermaking Machine at Carrongrove 58, 59
53. Three Sets of White's Driving Gear 60
—. 134-in. Papermaking Machine at the "Daily Telegraph" Mills, Dartford 61, 63, 65, 67
54. 102-in. Machine at Carrongrove—James Bertram Plate I
55. 134-in. Machine at Dartford—Bertrams' Plate I
56. Expanding Rope Pulley Driving Gear—Bertrams' 70
57. Expanding Rope Pulley Driving Gear—Bertrams' 70
58. Bertrams' Expanding Pulley Rope Drive applied to a Large Machine 71
59. Rope and Electric Drive—Bertrams' 72
60. Lumsden Belt Drive—James Milne 73
61. Lumsden Drive—Diagram 73
62. Belt Drive without Clutches—Bertrams' 74
63. Bertram and Happer Electrical Drive—James Bertram 75
64. Electrically Driven Machine—Bertram and Happer System 77
65. Action of Tube Roll 79
66. Typical Vacuum Box 79
67. Shaking Arrangement 80
68. "Shake" Adjustment 81
69. Wet End of a Typical Fourdrinier—James Milne 83
70. The Sciennes Wire Guide—Bertrams' 84
71. Greig's Spray Cutter—Bertrams' 85
72. Power-driven Leading Roll—Bertrams' 86
73. Cast Iron Stuff Chests—Milne 87
74. Cast Iron Stuff Chests—Milne 88
75. Stuff Catcher or Economiser—James Bertram 89
76. Rotary Vacuum Pump—Milne 90
77. Section of Milne's Vacuum Pump 90
78. Vacuum or Backwater Pump—Milne 91
79. Stuff Pump—Milne 91
80. Drying Cylinder End—James Bertram 92
81. Manhole Covers—James Bertram 92
82. Water Lifter for Drying Cylinders—James Bertram 93
83. Steam Connection—Bertrams' 93
84. Water Lifter, Steam Connection and Trap—Bertrams' 94
85. Felt Roll—Bertrams' 96
86. Strainer Plate in Section 97
87. Diagonal Rib Strainer Plate 98
88. White's Oscillating Strainer—James Bertram 98
89. Hinged Flat Plate Strainer—Milne 99
90. "Leith Walk" Full Drum Strainer—James Bertram Plate II
91. "Partington" Revolving Strainer—Glossop Ironworks Plate II
92. Detail of a Wandel Strainer 101
93. "Vibromotor" Strainer—Watford Engineering Works 102
94. Vibromotor Drive 104
95. "Dickenson" Strainer—Watford Engineering Works 104
96. "Leith Walk" Half-Drum Strainer—James Bertram 105
97. "Wandel" Strainer—Watford Engineering Works 106

FIG. PAGE
98. "Partington" Strainer—Glossop Ironworks 106
99. "Vibromotor" Strainer—Watford Engineering Works 107
100. A Fan Drum and a Driving Drum for Air Drying Machine . . . 110
—. Air Drying and Sizing Machine for Paper 112, 113
101. Diagram of Driving Arrangement for One Section of Air Dryer . . 116
102. Steam Drying Cylinders and Calenders 117
103. Rotary Brush Damper—Milne 119
104. Rotary Brush Damper—Milne 119
105. 42-in. Three-Roll Calender—West End Engine Works 121
—. 42-in. Three-Roll Calender—West End Engine Works 122
—. 130-in. Ten-Roll Super Calender—West End Engine Works 123
106. 130-in. Ten-Roll Super Calender—West End Engine Works 125
107. 90-in. Slitting and Winding Machine 127
108. 90-in. Slitting and Winding Machine—West End Engine Works . . . 128
109. Friction Drive Arrangement 129
110. Duplex Square Cutter—James Bertram 130
111. Small Square Cutter—West End Engine Works 131
112. Wood-Chopping Machine—Glossop Ironworks 135
113. Wood-Chopping Machine 136
114. Stationary Digester—Bertrams' 137
115. Revolving Digester—Bertrams' 138
116. Machine for Converting Wood Pulp into Dry Sheets—Bertrams' . . 139
117. Samples of Mechanical, Sulphite and Soda Wood Pulp 141
118. Art Paper Coating and Drying Plant—Mather and Platt 145
119. Coating Machine and Uptake End of Trackway 147
120. Downtake End of Trackway and Reeling Machine 149
121. Diagram of Art Paper Coating Plant—Masson, Scott 152
122. Art Paper Coating Machine—Mather and Platt 154
123. Art Paper Coating Machine—Masson, Scott 154
124. Coating Machine—Masson, Scott 155
125. Calender—Mather and Platt 157
126. Brushing Machine—Glossop Ironworks 159
127. Art Paper Brushing Machine—Glossop Ironworks 160
128. Gelatine Coating Machine 163
129. Photographic Emulsion Coating Machine—Masson, Scott 167
130. Photographic Paper Coating Plant—Masson, Scott 168
131. Photographic Paper Coating Plant—Mather and Platt 169
—. Photographic Paper Coating Plant—Mather and Platt 170, 171
132. Diagram of Chain Arrangement 172
133. Turntable and Downtake—Mather and Platt 173

LIST OF PLATES

PLATE
I. Two Typical Fourdrinier Papermaking Machines . . . . *Facing page* 57

II. Two Examples of Modern Pulp Strainers . . . . „ 100

III. Air Drying and Sizing Machine for Tub-sized Papers . . „ 109

IV. Arrangement and Details of Sizing Machine . . . . . „ 111

V. Art Paper Coating and Drying Plant . . . . . . „ 151

VI. Machine for Coating Photographic Papers . . . . . . „ 163

CHAPTER I

INTRODUCTORY

THE art of making paper as practised to-day is one in which the engineer and the chemist work side by side and have equal responsibility. In the following chapters we propose to deal with the construction and operation of the machines employed by the papermaker as supplied by British builders, that is to say, primarily with the engineering aspects of the art. But it would be quite impossible to do so if we were compelled to exclude all reference to the chemical aspects, so that in effect our work will cover practically the whole field of papermaking practice and should give the reader a good idea not only of the machines employed but of the various processes through which the raw material passes from the time it enters the mill until it leaves as the finished product.

It is very difficult indeed to define what paper is. One of the best definitions yet proposed describes it as "an aqueous deposit of vegetable fibre." This gives a clear idea of the fundamental process involved, namely, the deposition of fibrous matter, previously suspended mechanically in water, and its "felting" together in the form of a continuous sheet. The definition fails, however, because vegetable matter, while employed to a wholly preponderating extent, might be quite absent and yet the substance could reasonably be called paper. A more serious objection to the definition is to be found in the fact that it covers only the mechanical aspects of papermaking. Strictly speaking, the substance contemplated in the definition would be almost useless for nearly every purpose for which paper is to-day employed. Notably would it be so for writing and printing upon. To confer on it certain of its valuable properties the chemist must take it in hand -actually he works on it simultaneously with the engineer - and add to it certain mineral and other substances such as china clay, starch, alum and resin, not to mention various bleaching and colouring reagents. These materials fill up the interstices between the fibres, toughen the cellulose of which they are composed, "size" the paper so as to render it kindly to the pen, remove its objectionable tinge and alter it to a pleasing one. All these benefits are clearly of sufficient importance to merit recognition in the definition.

Having thus cleared the ground as to what paper is, we should properly touch upon the history of its manufacture. This is a subject, however, so controversial in many of its details and dates that we feel some dubiety about the wisdom of presenting even the following brief outline of it.

Papyrus, parchment and vellum not being admissible as paper, we have, according to the best authorities, to go to China to discover the earliest known traces of the manufacture of true paper, that is, of a felted aqueous deposit of fibrous material. Somewhere about 750 A.D. the Arabs acquired the art from the Chinese and introduced improvements into it. Thus, by the end of the eighth century the Arabs were employing linen rag as almost the sole basis of their paper, and had learnt to load and size it with starch. From the Arabs, through the Moors, the art was introduced in the eleventh century into Spain, whence it spread into Italy, France and the Netherlands, and later on into Germany. For many years this country had to supply its needs by importing its paper from the Continent, and not until 1495 is there any evidence that the industry was being practised within our shores. About that year one John Tate set up a mill at Stevenage, Herts. Others took it up slowly, but until the Revocation of the Edict of Nantes in 1685 we still depended almost entirely on the continental sources of supply. About ten years before this date, it is interesting to note, the mills at Wolvercote, Oxford, were established, and at the present day these mills are still manufacturing the well-known Oxford India paper. With the incoming of the Huguenots the art of papermaking, like so many others in this country, received much stimulus, and from then onwards its development followed along ordinary lines.

In 1725 a monopoly was granted to De Portal, of the Laverstoke mills in Hampshire, for the manufacture of paper for Bank of England notes. Messrs. Portal of to-day still make this paper. In 1739 it was officially recorded that there were 278 paper mills at work in England manufacturing on the average about ten reams per day each. In the same year James Whatman established a mill at Boxley, Maidstone, and introduced considerable improvements into the industry. His name is still associated with a certain class of paper beloved especially by water-colour artists.

All this time the paper manufactured was what is called "hand made," that is to say, the deposition of the fibrous material from its aqueous state was carried out on a wire frame or strainer manipulated by the worker. No little skill was required for this operation, but as the frame or mould could be shaken in all directions, the result, if the process was skilfully conducted, was a paper in which the felted fibres crossed one another at all angles. It is to this circumstance that hand-made paper owes its many superior properties, for in machine-made paper the action, as we shall see, encourages the fibres to lay themselves all in one direction. Nevertheless, hand-made paper could not be made in anything but sheets of strictly limited size. Such a thing as a roll of paper four to five miles or so in length as employed by the daily and other press of to-day was inconceivable. Inspired probably by the pending developments of the printing machine, efforts were made towards the end of the eighteenth century to surmount the limitations of size imposed by the use of a hand mould and to devise a machine that would turn out paper in sheets or rolls of practically unlimited length. The earliest of these efforts was, we believe, made in France, and met with something like success after much experimentation. But it was in England that the idea was reduced to a commercial basis.

The name of Messrs. Fourdrinier, wholesale stationers, of London, will always be remembered in this connection. From the idea as communicated to them from France they set to work at Bermondsey, and with the assistance of Mr. Bryan Donkin in 1803 turned out and installed a really practical machine. Many difficulties had to be overcome and much money spent on making improvements, but by 1810 success was assured. By 1851, the year of the Exhibition in Hyde Park, the Bermondsey works had turned out a total of 190 machines.

We will not attempt to trace the historical development of the many subsidiary machines employed by the papermaker. These date some from before the invention of the papermaking machine proper and some from after. All have been very considerably developed since the early years of the nineteenth century.

Backward at first in the art of making paper, this country, as in so many other instances, has in time acquired one of the foremost places in the industry. Her engineers, too, have advanced with the times, and to-day the papermaking machinery of all types which they turn out has a world-wide reputation. We have been unable to obtain any satisfactory figures revealing the position occupied by our engineers in the world's markets for papermaking machinery. But if we may suppose that it is much the same as the position occupied by our paper manufacturers—and there is some reason in thus supposing—then we may say that while our machinery is in good demand abroad we have had powerful rivals in Germany. Statistics show that in 1912 Germany exported to all destinations paper, pasteboard and cardboard valued at five and a quarter million pounds, while our exports—in 1913—were valued at just about one half of that amount. Austria-Hungary in this department was by no means a rival to ignore, her 1913 exports being returned as something over a million pounds. In her case, however, we may doubt if this implies a proportionate share of the paper machinery trade. As is well known, Germany before the war supplied a very considerable share of the paper, &c., used in this country. Thus, in 1912, her exports to us reached in value to more than one and a quarter millions. Our exports to her in return were almost insignificant.

Before taking up the description of British-made papermaking machinery it will be of assistance if we briefly review the entire process of papermaking from start to finish. From the outset it should be made clear that papermaking divides itself naturally into two broad stages, namely, the preparation of the pulp—that is, of the aqueous stuff containing the disintegrated fibrous material—and the conversion of this pulp into dry sheets of paper. Usually the product at the end of the second stage is ready for the market, but in some cases a certain amount of after treatment is accorded it.

The raw material employed by the papermaker, in all but a few instances not worth mentioning, may be described generically as cellulose. Chemically considered, cellulose is a carbo-hydrate having the empirical formula $C_6H_{10}O_5$. Physiologically it is the main product of vegetable life and when isolated is presented to us mainly in the form of thick or thin-walled flattened tubes. It is to this form that we owe its "felting" properties, but its chemical nature is also of first importance to the papermaker. Not only is it quite insoluble in water, but it is very nearly impassive to oxidising influences and is extremely resistant to alkalies. Without these chemical properties the substance could not be made into paper, at least as we know it.

The quantity of cellulose contained in vegetable fibre varies with the source from which the fibre is obtained. Of all sources that of cotton contains the biggest percentage of cellulose. Cotton fibre contains about 90 per cent. of cellulose, 7 or 8 per cent. of water, 0·4 per cent. of wax and oil, 0·6 per cent. of nitrogenous matter, and about 1 per cent. of mineral ash. Flax comes next with about 82 per cent. of cellulose. The wood of the pine tree is some distance down the list with 57 per cent., while bamboo, esparto grass, and straw are still lower with from 40 to 48 per cent. Nor is the cellulose always of the same chemical formation. The cellulose of cotton, flax, and hemp corresponds in composition with the chemical formula given above, but the cellulose of jute, straw, esparto, and so on may vary 1 or 2 per cent. as regards the quantity of each constituent. The former is true cellulose; the latter may be regarded as partially hydrated cellulose.

It may be remarked in passing that cellulose, the basis of paper, is also the basis of many another industrial product, and that its chemistry is connected with one of the most interesting chapters in the whole field of technology. Apparently it is nothing more than six atoms of carbon associated with five molecules of water. Yet treat it with nitric acid and we get the chief constituent of gun-cotton. Add camphor to the above nitro-cellulose and celluloid is obtained. Treat cellulose with mineral acids and dextrose, or glucose as it is called commercially, may be formed. Dissolve nitrated cellulose in alcohol and ether. The solution squirted through fine holes evaporates quickly and solidifies into threads of artificial silk. Shake a mixture of cellulose and caustic soda with carbon bisulphide in a closed vessel. A substance is produced called viscose, which, if allowed to coagulate, forms a hard mass that can be turned and polished, or if spread on glass coagulates in the form of a tough transparent film.

Papermaking, however, once the cellulose has been extracted from the raw material, is a mechanical rather than a chemical process—that is to say, it does not seek to change the chemical nature of the raw cellulose, but preserves it as such in the finished product.

For many years cotton and linen rags, whether collected as the waste of textile mills or from more domestic sources, formed the principal raw material of the papermaking industry, and for high-class writing and printing paper such rags are still in demand. Rags, it may be pointed out, are preferred to raw cotton or linen, not only because they are considerably cheaper, but because the material, having been spun and woven, yields a much better paper than the raw stuff. In 1860 esparto grass obtained from Spain and North Africa was introduced by Mr. Thomas Routledge as a raw material, and has ever since been used very extensively for high-class printing and medium quality writing paper. It has many valuable properties and gives a printing paper possessing a good surface combined with flexibility and softness. About the same date straw as a raw material began to be used extensively for the production of news and other printing paper not of a high-class quality. It is still so used as well as being converted into box, card, and straw board. Later on, about 1870, wood pulp obtained from Norway, Sweden, Canada, or the States came into very extensive favour for the production of cheap papers for writing and printing, and to-day is almost universally employed by our newspapers. Flax in the form of waste from the spinning mills, hemp in the form of refuse, old rope, sailcloth, &c., and jute waste and old bags provide another class of raw material used principally for the manufacture of wrapping paper.

With the exception of the wood pulp, which is received at the mills in a condition almost ready for the papermaking machine proper, all these materials have to be passed through four distinct processes before they reach the pulp stage. These processes are known as cleaning, boiling, bleaching, and beating. The machines employed in them differ somewhat according to the nature of the material being treated and will be fully described in later chapters. In the first process an attempt is made to remove by mechanical means all adventitious foreign matter, such as sand, dirt, buttons, hooks and eyes, &c., from the raw material. The second process is, properly speaking, a chemical one. It consists in digesting the cleaned material in an aqueous solution of caustic soda, the boiling being done under pressure. Caustic soda, as we have already said, has no action on cellulose, at least in the strength in which it is here employed, but it attacks the non-fibrous parts of the raw material, the oil, wax, &c., and also any grease or dirt still adhering to it, and converts these substances into soluble compounds. The result is that the material is broken up, as it were, and the long thin cells are more or less completely separated from one another. The boiling process is not simply a method of completing the cleaning of the raw material. It should be regarded philosophically as a chemical means of splitting it up and isolating its cellulose.

The disintegrated stuff having been carefully washed to free it of the alkaline liquor, is next bleached in a solution of calcium hypochlorite—bleaching powder—or in a solution of sodium hypochlorite obtained electrolytically from common salt. The material is again washed and purified and is frequently concentrated before being passed on to the beating engine wherein the fourth stage is completed. The object of this beating process is to break the individual cells into fragments about five or six-hundredths of an inch in length and to complete the separation of the fibres begun during the boiling operations. In the case of esparto grass, straw, &c., the natural length of the fibres is very near the figure required, but in flax and cotton the fibres may have lengths of as much as $1\frac{3}{16}$ in. The beating has therefore to be much more drastic with the latter than with the former. During the beating operations it is customary to add any loading, sizing, and colouring materials to the pulp that may be required.

The pulp is now ready to be made into paper. We will not attempt at this stage to describe a modern papermaking machine, but it will assist us to do so later if we indicate now the manner in which the pulp is converted into paper by the old-fashioned hand method.

The pulp, considerably diluted with water, is first run from the storage chests through a screen or sieve for the purpose of removing any foreign material or any of the fibres which may not have been sufficiently reduced in size. Thence it is passed into a vat. The next process is one requiring great skill on the part of the operator, the vatman, as he is called. The hand mould which he employs consists of a rectangular wooden frame, across which wire cloth is tightly stretched, and a second, but open, frame called a "deckle" fitting on to the first and forming the edges of the mould. This tray is dipped by the vatman into the pulp and is withdrawn with just that amount of material on it that will give the required thickness of paper. As the water of the pulp drains through the wire cloth the vatman shakes the mould laterally and causes the fibres to "felt" together at all angles to one another.

The deckle is then removed and the mould passed across to a second workman known as the coucher, who transfers the wet sheet of paper on to a piece of felt. When a pile of such felts and sheets has been accumulated it is transferred to a press, where the surplus water is squeezed out and the paper compressed and closed up. Thereafter the felts may be removed and the sheets piled by themselves and subjected to a further pressing with the idea of causing the irregularities of one sheet to obliterate those of another. The sheets are then hung up to dry in a suitable room.

The pulp used for hand-made paper is not usually sized beforehand. The sizing is accomplished by dipping the dried sheets into tubs containing a solution of gelatine and alum. This converts the paper from an absorbent material that will readily suck up water into a substance more or less as we know it when finished. The sheets having been dried are glazed or "calendered," whereby the dull rough surface is changed to one that is more or less highly polished and smooth. One method of effecting this is to pass a pile of sheets each separated by a zinc, or copper polished plate, through a heavy pair of rolls. The greater the pressure applied and the more thoroughly the rolling is carried out the higher will be the polish. The surface may be still further enhanced by heating the metal plates. This calendering process is not employed solely for the sake of the improved surface which it gives the paper. During the rolling the fibres are compressed and the material is consolidated so that its thickness may be reduced by very nearly a half. This greatly improves the paper in every way, notably increasing its tensile strength. If carried too far, however, it makes the paper brittle and liable to crack when handled.

After calendering the paper is ready for the market.

CHAPTER II

CUTTING, CLEANING, AND BOILING

With this chapter we commence the description proper of certain typical British-made machines used in the art of papermaking. We have not found it an easy matter to make our selection, for papermaking is such a vast subject and the machinery employed in it is so varied that it is quite impossible in a work such as the present to cover or even mention every ramification. No two paper mills follow exactly the same methods of producing paper even from the same raw material, and if the departure is at all great the plant used will be specially designed for the mill and will not be found anywhere else.

On the other hand, there are many standard types of different machines which are manufactured with little variation, or none, by nearly every paper machinery engineer in the country. This fact should be borne in mind, for we desire to avoid creating the impression that this book may be taken as a guide to what such and such a maker named herein does and does not make. We believe we are right in saying that with the exception of one of the firms on our list, which specialises very largely in pulp strainers, any class of machine which is not patented may be obtained from any of the firms named in the following chapters.

We have endeavoured in our selection to pay special attention to recent improvements in the paper machinery field. But in order not to appeal solely to the reader who already possesses a knowledge of papermaking and its machinery, we have included descriptions of certain standard types of machines. The result is a more or less connected account of the art of papermaking as viewed by the engineer, in which there are, at any rate, but few gaps of fundamental importance. The diversity of purpose, the many interesting problems which have been and yet remain to be solved, and the ingenuity displayed on almost every hand, makes the field of papermaking a most entrancing one to the general engineer, and to him especially we trust the descriptions which follow will appeal.

In the case of such raw materials as esparto, rags, straw, &c., the earliest treatments in the mill are intended to clean out any adventitious foreign matter, such as dust, from the material and, if necessary, to reduce the original stuff to such size as will facilitate its proper digestion in the boiler. Certain of these cleaning and cutting processes, particularly in the case of rags, are still frequently performed solely by hand. The tendency, however, is more and more towards the employment of machinery.

The first process for which the engineer has to supply machinery is the cutting or chopping of the selected material into suitable sizes or lengths. This cutting process is, in particular, in use if the raw material takes the form of linen, cotton or other rag, but it is also in use for dealing with old ropes, straw and, in fact, any material the natural length of which is greater than can be handled conveniently and with efficiency in the digesting boiler. We describe three machines of this nature.

In Fig. 1 we illustrate a cutting machine made by Bertrams Limited, Sciennes, Edinburgh,[1] and intended for chopping up rags, ropes, bagging and suchlike material. It consists of a heavy revolving cast iron drum carrying three steel knives and a fixed or dead knife attached to the bed. The drum is either 4 ft. or 5 ft. in diameter and is enclosed within a wooden cover. The material is fed between the revolving knives and the dead knife from a table. As indicated in the diagram—Fig. 2—the actual feeding is performed by a grooved feeding-in roll driven by belt from the drum shaft. This feeding-in roll is adjustable vertically either by the hand or the foot lever shown in Fig. 1, thus permitting the thickness of material being cut to be varied. From the dead knife the cut material falls on to a curved sheet steel plate beneath the drum and is delivered through the end of the casing on to the floor behind the machine. The wooden cover is shown removed in Fig. 1. Its object is to prevent the rags and dust from being scattered over the neighbourhood. The drum is driven at a speed of about 200 revolutions per minute. The horse-power absorbed by the machine is about ten. In a ten-hours' day the output is roughly five tons of chopped rope or about eight tons of chopped cotton rags.

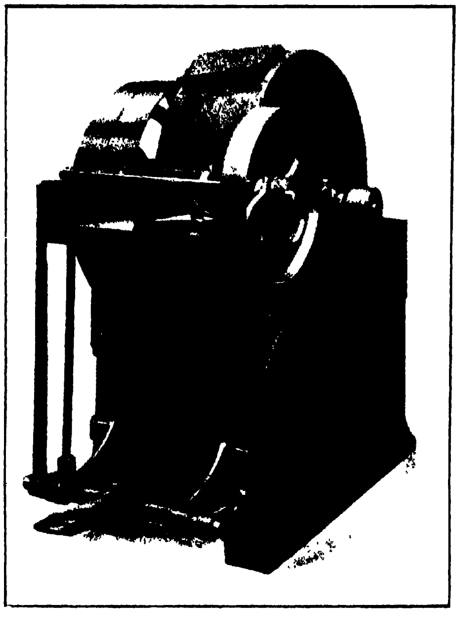


FIG. 1.—Bertrams' Rag Chopper.

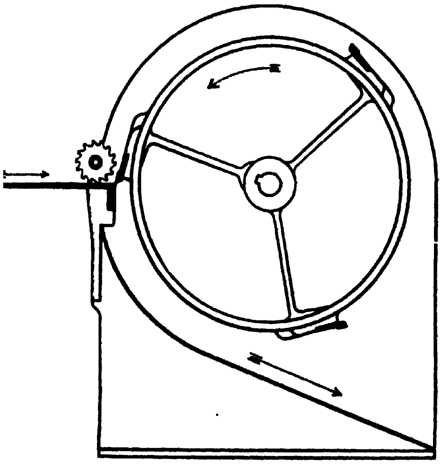
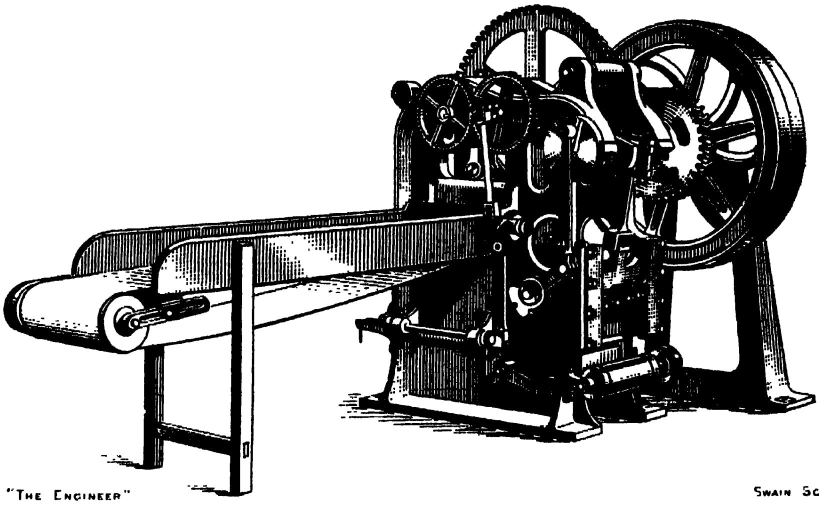


FIG. 2.—Bertrams' Rag Chopper.

A machine for chopping rags, known as Nuttall's patented rag cutter, and made by James Bertram and Son, Limited, of Edinburgh, is illustrated in Fig. 3. This machine is provided with two guillotine knives sliding in guides at right angles to each other. Each knife is driven by a crank and connecting-rod. The uncut material is deposited on the endless felt belt shown, which conducts it to the first knife. The cut portions fall on to a second belt within the framework of the machine, which carries them over to the second and lower knife. The material is thus cut into pieces which are approximately square. The felt bands are driven by ratchets operated from the ends of the crank shafts. By varying the throws of the ratchet cranks the speed of the bands can be altered and the size of the pieces cut regulated accordingly. The size can be varied from 1 in. square upwards. The output is from 20 cwt. to 30 cwt. of cut rags per hour. The usual width of the knife gap is 21 in. Ropes as well as rags can be cut with this machine.

---

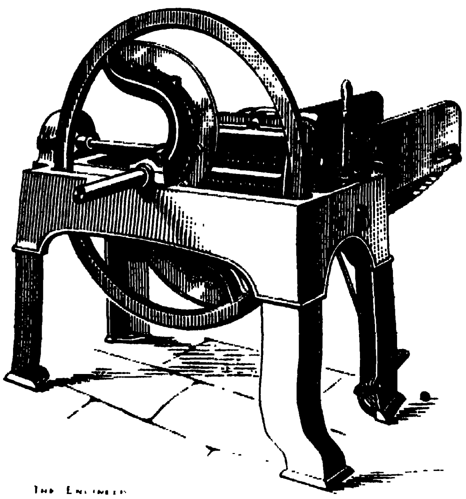
[1] The two firms, Bertrams Limited, St. Katherine's Works, Sciennes, Edinburgh, and James Bertram and Son, Limited, Leith-walk, Edinburgh, should not be confused with one another. Under the appropriate illustrations throughout this work we use "Bertrams'" to indicate the former firm and "James Bertram's" to indicate the latter



"The Engineer" Swain Sc.

Fig. 3.—Nuttall's Rag Cutter—James Bertram.

For chopping straw, preparatory to boiling it, a machine resembling a strongly constructed chaff cutter is used. An example made by James Bertram and Son, Limited, is illustrated in Fig. 4. It consists of a revolving wheel carrying, fixed to its arms, three curved knives and a "dead" knife fixed horizontally to the frame. The straw is fed up to the dead knife by means of an endless web and two toothed rollers. It is usual to find the straw cut up into pieces 1 in. to 2 in. long. After cutting, the knots are removed either by hand picking or in a separating machine.



The Engineer Swain Sc

Fig. 4—James Bertram's Straw Chopper.

The material cut on the above machines and other material, such as esparto, which can be dealt with without resorting to cutting, has to be cleaned. There may be buttons, hook and eyes, &c.. adhering to the rags. These are removed usually by hand. All the materials are probably charged with dust and sand. This is removed by machinery in a purely mechanical manner. Two examples of dusting machines, or "willows" as they are called, one intended principally for dealing with rags and the other for grass, are illustrated. Both are chosen from the practice of Bertrams Limited, Sciennes, Edinburgh.

The machine illustrated in Figs. 5 and 6 is intended for teasing out and dusting out rags, ropes, bagging, jute, &c. It is in two parts, the teasing part—or "willow" proper—and the dusting part. The cut material is delivered on to an endless revolving band, and is thence fed into the willow. This consists of two rotating drums provided with longitudinal rails to which iron spikes are fixed. These spikes stagger with rows of stationary spikes fixed to the top of the casing and subject the material to a thorough teasing out. The lower portion of the willow casing is provided with a false bottom, through the slits of which the dust liberated during the teasing process may pass while the rags are held back.

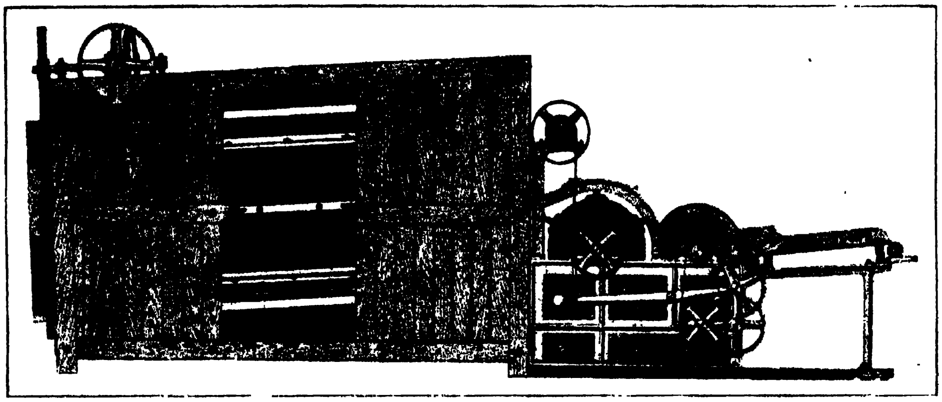
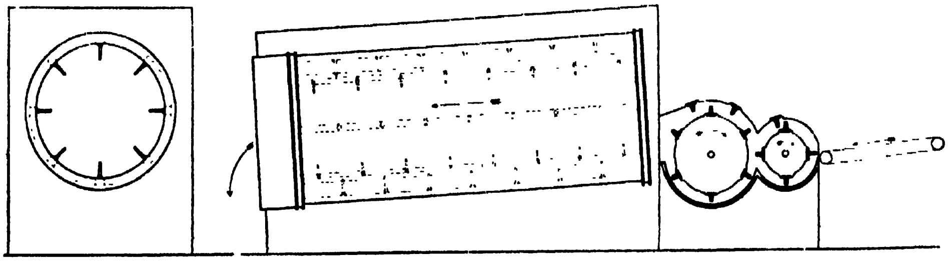


Fig. 5.—Bertrams' Willow and Duster.

At regular intervals a door at the end of the willow casing is opened by a self-acting drive to admit the material from the willow into the duster. The latter consists of a wooden casing containing a revolving drum some 4 ft. in diameter by 12 ft. in length. The ends of the drum are open and are supported on friction rollers. The body of the drum is formed of galvanised wire netting carried on eight longitudinal rails, each of which has affixed to it a series of iron spikes. The material within the drum is lifted and tossed about. The dust shaken from it falls through the netting to the floor, and is thence extracted by a fan. The dusted material, owing to the axis of the drum being inclined, is gradually worked down to the lower end.



"The Engineer" Swain Sc.

Fig. 6.—Bertrams' Willow and Duster.

The two machines have separate driving gears, so that if desired they may be operated independently. The horse-power consumed when both are working simul-

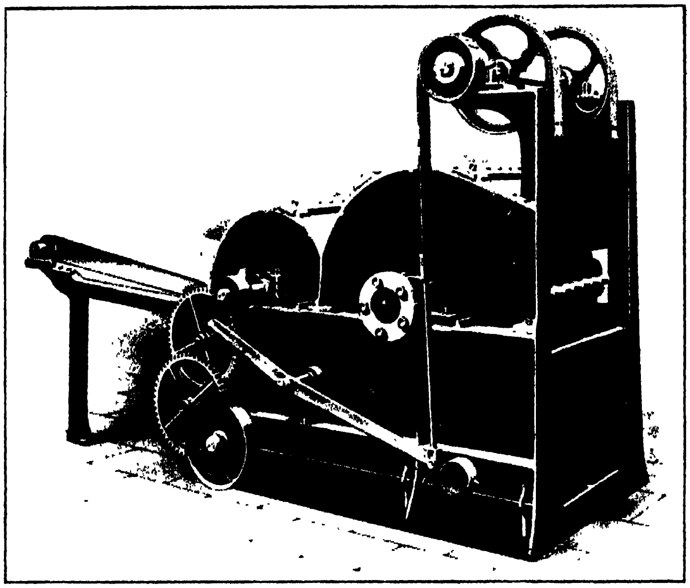


Fig. 7. Bertrams' Double Drummed Willow.

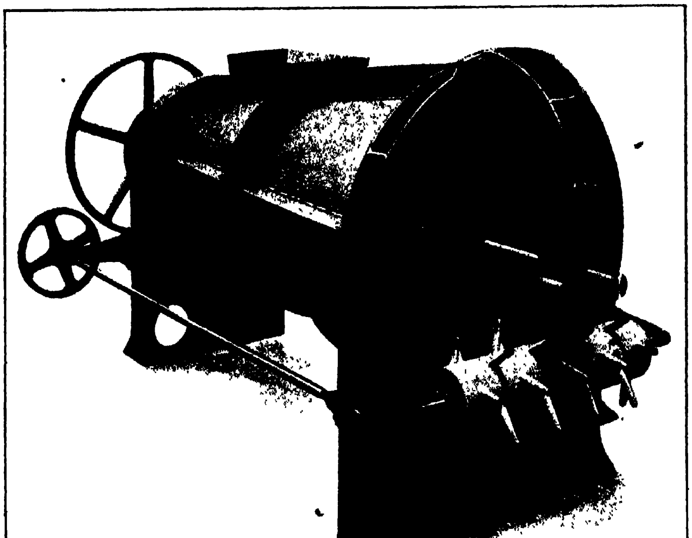


Fig. 8.—Bertrams' Conical Grass Duster.

taneously is about 12. The willow drums have a speed of about 220 revolutions per minute, while the duster drum revolves at about 12. An output of a ton of rags per hour can, we are informed, easily be obtained.

In Fig. 7 we give a view of the double-drummed willow separately, with the side covers removed to show the interior arrangement.

The machines just described can be modified to make them suitable for cleaning straw and certain other materials. But in general we may say that straw, esparto and other raw materials of the grass class are best cleaned in a conical duster of the type shown in Figs. 8 and 9. In this we have a five-sided revolving cone with closed ends, and provided with a row of spikes along each of the five edges. This cone rotates within a circular conical casing, carrying at the top a row of spikes with which those on the drum intermesh. The bottom half of the casing is formed of wrought iron or steel bars, so spaced as to allow the dust but not the material to fall through to the floor beneath. The grass is fed into the casing through a hopper at the smaller end and finds its own way down to the larger or delivery end. Here a revolving rake is fitted to carry the dusted material on to an elevator or conveyor band. On each side of the casing a sheet iron wall—not shown in the engravings—extends from the centre line level to the floor. These form a chamber from which the dust is removed by an exhaust fan. The drum runs at about 250 revolutions. The horse-power required is from 8 to 10, and the output from 30 cwt. to 40 cwt. of grass per hour.

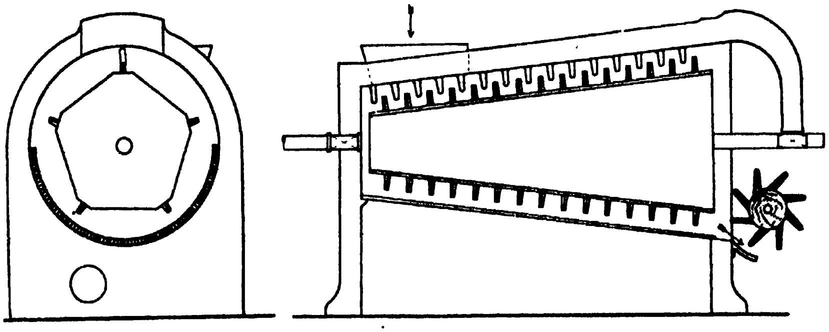


Fig. 9. Bertrams' Conical Grass Duster.

The cleaned material is next boiled or digested in an alkaline solution, usually of caustic soda, the process being carried out under pressure. The amount of alkali solution used and its strength varies very greatly at different mills, as does the pressure. The latter may be anything from 5 lb. to 60 lb. per square inch, while the former may be from 5 to 70 per cent. of the weight of the raw material. The higher the pressure employed and the longer the digesting process is kept up the less solid alkali will be required.

The chemical function of the boiling process is, simply put, to convert all the non-cellulose parts of the raw material into soluble compounds and to split up the cellulose part more or less completely into its constituent fibres by dissolving out the "cement" holding them together. The boilers employed for the purpose are very commonly either spherical or cylindrical with spherical ends, and nearly always nowadays are arranged to be revolved continuously on a horizontal axis. The spherical type is used principally for boiling rags and straw. Except for its shape, it differs very little from the cylindrical type, of which an example from the practice of Bertrams Limited, of Edinburgh, is shown in Fig. 10.

The shell of this boiler is made of Siemens-Martin steel, and is commonly about 8 ft. in diameter by about 22 ft. long on the parallel part. In the position shown in our engraving, we have two filling and emptying doors on the top, two blow-off cocks beneath and directly opposite the doors, a steam inlet cock with a connecting pipe and gland at the left-hand trunnion, and a steam blow-through cock similarly affixed to the unseen right-hand trunnion. A pressure gauge and safety valve are usually provided on the steam connection at the left-hand trunnion.

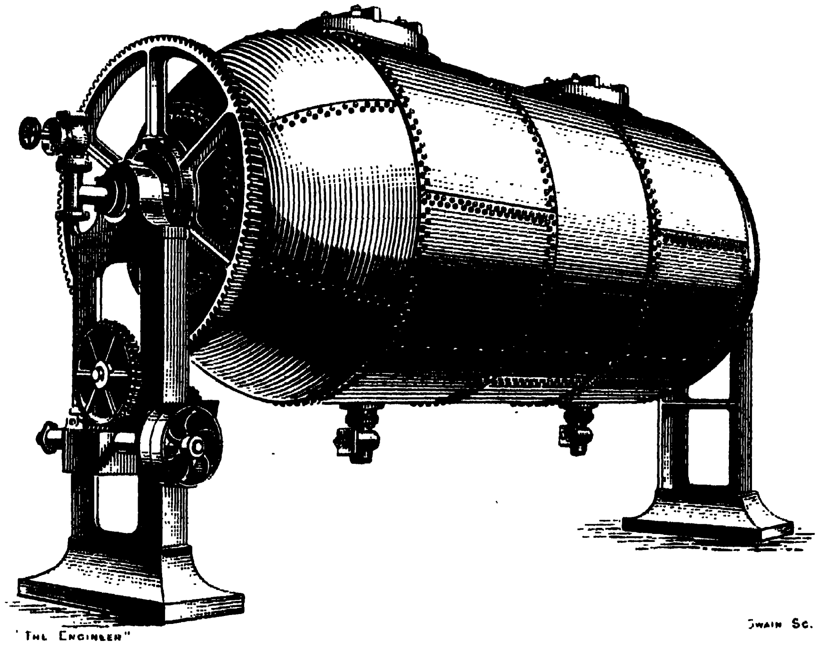


Fig. 10.—Bertrams' Revolving Cylindrical Boiler.

From the inlet cock the steam is led through an internal malleable iron pipe into a chamber formed over the blow-off cocks and provided with a perforated top. It passes thence through the fibre to the blow-through cock on the right-hand trunnion, the entrance to which is guarded against the passage of material into the exhaust pipe by a perforated baffle plate. During the whole period of boiling, which may last for from three to six hours, the boiler is revolved continuously by power at the rate of one revolution in three minutes. The horse-power required for this purpose is not more than 3. When the process has been completed, the blow-off cocks are opened and steam shut off. The liquor is thus discharged into a drain below the boiler, while the material is held back by the perforated baffle extending over the blow-off cocks. It should here be stated that the liquor thus discharged is carefully collected and the soda recovered from it for future use. We do not propose to describe the soda-recovery plant, although we may say that it is obtainable in this country from Bertrams Limited, and from other firms.

The capacity of the above boiler for the dimensions given is sufficient for five tons of rags. The steam pressure recommended by Messrs. Bertrams is from 20 lb. to 30 lb. per square inch.

The boiling of esparto grass cannot be conducted satisfactorily in a revolving boiler, for if this material is agitated to any degree the fibre is apt to form a mass that will oppose the proper permeation of the caustic soda lye. The form of boiler almost invariably adopted for boiling esparto grass is that known as the "vomiting" type. In Fig. 11 the section of such a boiler as made by James Bertram and Son, Limited, of Edinburgh, is shown. It consists of a cylindrical steel shell with a filling door at the top and an emptying door on one side near the foot. A perforated plate is fixed close to the top and forms with a suitably flanged piece an annular chamber, from which the soda lye can shower down on to the grass beneath. The grass rests on a second perforated plate situated near the bottom. A false bottom just beneath this perforated plate forms, as it were, a tray for the reception of the lye after it has passed through the grass. Two or more vomiting funnels, as shown in the plan, are attached to the inside of the shell and form a connection between the tray at the foot and the annular space at the top.

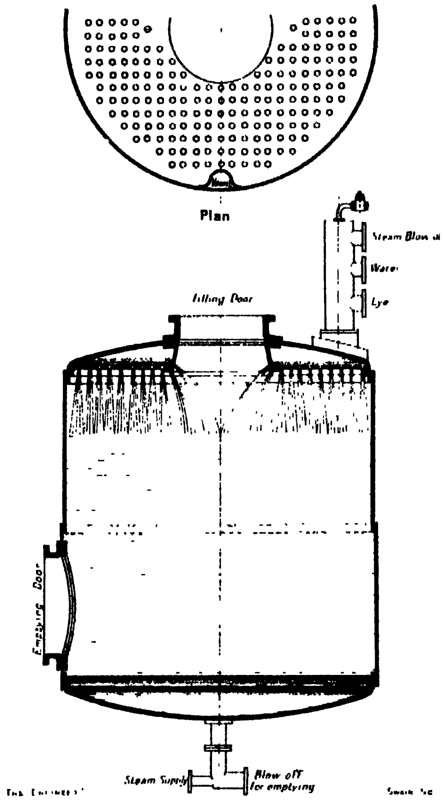


FIG. 11.—James Bertram's Esparto Boiler.

A suitable standard on the top end-plate provides a means for admitting the lye and the requisite amount of water separately. There are also at this point a steam blow-through valve, whereby any desired pressure may be maintained within the boiler, and a safety valve. On the bottom end-plate is fixed a connection providing a steam supply to the space beneath the false bottom and a blow-off leading from the tray. The boiler having been charged with grass, the lye and water in the proper proportions are admitted to the annular space. The liquid finds its way through the grass to the tray and into the vomiting funnels. The doors being tightly closed, steam is turned on beneath the false bottom. Suitable means have, of course, to be provided for removing the condensed steam, at the proper rate. The boiling liquid completes the ascent of the vomiting funnels and is poured over the top perforated plate, whence it descends again through the grass to the tray. The circulation is continuous and is kept going for about five hours, although this time is variable according to the pressure allowed to exist within the boiler.

After the boiling has been completed the liquor is run off and cold water is admitted to the boiler from the connection on the standard at the top. This effects a preliminary washing of the fibre and at the same time cools it sufficiently to permit it to be readily handled by the workmen.

An external view of an esparto vomiting type boiler, as made by Bertrams Limited, is given in Fig. 12. The construction of this is practically identical with that of the boiler illustrated in Fig. 11. The engraving, however, shows the method adopted for fastening the filling and emptying doors. Messrs. Bertrams recommend for these boilers a pressure of from 40 lb. to 50 lb. per square inch. It may be taken that with such pressures the amount of caustic soda used is about 14 lb. of 70 per cent. soda to each ton of grass. This figure, however, varies with the quality of the grass being treated, quite apart from the pressure adopted. The usual size of an esparto boiler is 9 ft. in diameter by 9 ft. high on the parallel part. Such a boiler will have a capacity for from 2½ to three tons of esparto. Four of them are capable of treating 100 tons per week.

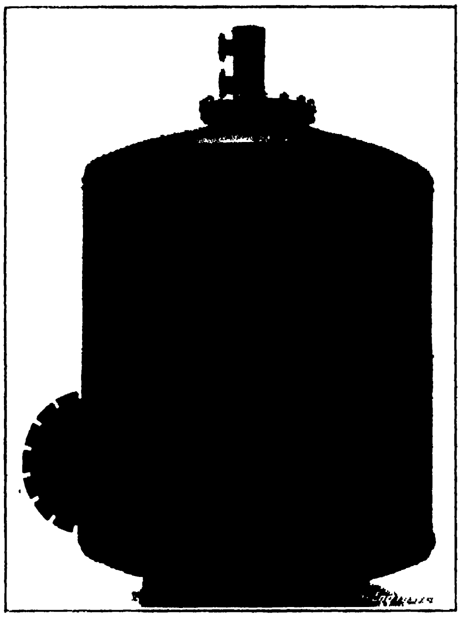


FIG. 12. Bertrams' Esparto Boiler.

Esparto grass contains about 48 per cent. of cellulose, or about half that contained in rags, and therefore requires a more drastic digesting process. This the vomiting type of boiler described above provides without subjecting the fibre to an excessive amount of agitation. The thorough impregnation of the fibre with the caustic soda solution and the length of time for which the boiling or digestion process is kept up are the chief factors relied upon to secure the required degree of treatment. Although the ordinary revolving rag boiler is unsuitable, for the reason stated, for boiling esparto, the esparto boilers described above are quite suitable and are frequently used for boiling rags.

CHAPTER III

WASHING, BREAKING, AND BLEACHING

After the material has been boiled or digested it is usual to give it a preliminary rough washing in the boiler itself. The sequence of processes through which it subsequently passes before it reaches the stage of being finished pulp may be set out thus:—

Washing.—The caustic soda solution still remaining in the fibre after the preliminary washing in the boiler has to be very thoroughly removed. This is necessary both for the sake of the fibre and in the interests of economy. These interests, apart from the Rivers Pollution Act of 1876, dictate the recovery of the soda.

Breaking.—The fibre is, after boiling, apt to be formed into masses or bunches and has to be broken up and reduced to an aqueous mass of the required uniform consistency.

Bleaching.—A clear solution of bleaching powder is added to the stuff and is thoroughly incorporated with it.

Purifying.—The bleaching solution having done its work, has to be removed from the pulp, along with all the soluble impurities which it has created or extracted. The purifying process may roughly be said to consist merely of draining off the aqueous liquid from the fibrous stuff.

Washing.—The fibrous material may still have clinging to it some insoluble impurities, and in the moisture with which it is saturated there is bound to be present a certain amount of dissolved bleaching powder. A second washing with clean water is resorted to for the removal of these substances.

Beating.—The preceding processes have resulted in the splitting up of the raw material into more or less pure cellulose on the one hand, and various non-cellulose matters on the other hand, the removal of the non-cellulose portions and the isolation of the cellulose portion into individual fibres. To all intents the fibres, except that they are separate, are still in the form in which they were present in the raw material. The breaking process has helped to separate them, but has not fractured them. The fibres may be anything from $\frac{1}{16}$ in. long, as in esparto grass, to as much as $1\frac{3}{16}$ in., in flax. The beating process is intended to tear the fibres so as to reduce them to lengths of from $\frac{1}{32}$ in. to $\frac{1}{16}$ in. and to bring them to such a state that they will readily "felt" together into a sheet of paper. Obviously, felting power will be best secured by tearing the fibres rather than cutting them.

Loading, Sizing, Colouring.—Suitable materials are added to the pulp to occupy the interstices between the fibres in the finished paper, to render the finished paper resistant to ink, and to neutralise the yellow tinge which is nearly always present to a slight degree in bleached pulp.

Refining.—It is still possible that after beating is complete small portions of fibre may cling together in tiny masses. However carefully the beating is conducted it is also possible that some of the fibres may escape from it only partially, if at all, reduced. The process of refining is adopted in order to catch such pieces, to hold them back, and to open them out or reduce them before allowing them to pass on.

We have, in the above, set out all the processes separately. In reality certain of them are conducted simultaneously in the one machine. Thus, the first washing and the breaking processes are nearly always conducted in this manner. The third process, bleaching, is very often carried out immediately afterwards in the same machine. In some cases, however, a separate but very similar machine known as a potching engine is employed for the bleaching process.

The next process, purifying, is of an entirely different nature and requires a quite different class of machinery. For long it was conducted on machines known as presse pâtes. These are now being displaced by machines known as concentrators, a name which gives a clear idea of their function. The fifth process, washing, to remove the insoluble impurities, &c., left after bleaching and concentration, may be conducted in the washing and breaking engine first used. At times, however, it is carried on in the beating engine before the actual beating operation is commenced. The loading, sizing and colouring materials are usually added to the pulp while it is being beaten, as this brings about their thorough incorporation with the fibres. When this course is followed the second washing has, of course, to be conducted beforehand.

The process of refining is carried on in machines of a variety of forms and differing materially from all the preceding types. The refining engine is usually a separate machine, although at least one British firm makes a combined beating and refining engine.

The machines used for washing, breaking, bleaching and beating, in whatever manner these processes are combined or kept separate, are very generally members of a common family, the parent of which was the beating engine introduced about 1670, and still known from the country of its origin as the hollander. The chief characteristic feature of this class of machine is the form of the tank or vat in which the material is treated. In Fig. 13 a sketch is given showing the general form of the vat in section and plan. The vat is a receptacle having parallel sides and round ends and provided with an incomplete central partition known as the "mid feather." On one side of the mid feather the floor of the vat is flat and horizontal. Passing clockwise round the end of the feather the floor slopes gradually upwards to the mid-point, then rises suddenly to a crest known as the "back fall" or "weir." Thereafter it drops down to its former level and may be washed into the plane of the floor on the other side of the feather in a smooth curve, or may be dropped down as shown in the diagram by means of a small curved step. Across the middle of the vat a driven shaft extends, carrying a drum, the construction of which varies according to the exact purpose of the engine. In most cases the drum co-operates with knives or bars carried on an adjustable frame or "bed-plate" fitted

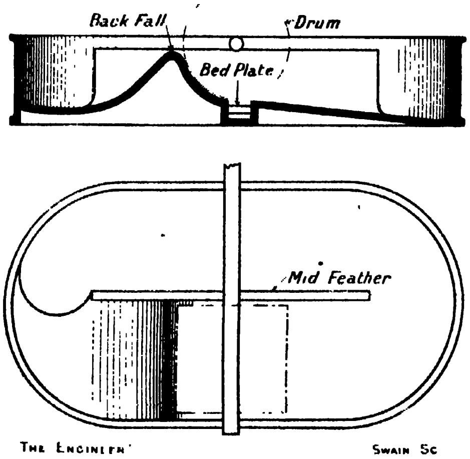


FIG. 13.– Diagram of a Hollander.

within a recess in the floor beneath it. All corners in the vat are provided with big fillets in order that there may be no lodgment of the pulp at any point.

In Fig. 14 an example of a breaking and washing engine intended particularly for dealing with esparto grass, and made by James Bertram and Son, Limited, of Edinburgh, is shown. The vat is made of cast iron sections bolted together, and may have a capacity of anything from 15 cwt. to 30 cwt. of dry grass. The drum on the near side of the central shaft is of cast iron in one piece, and is provided round its periphery parallel with its shaft with a number of equally spaced steel bars or knives. On the bed-plate, the end of which is seen at A, several similar knives are carried. By means of the hand wheel B the distance between the two sets of knives is carefully adjusted to give the desired result, namely, the opening out of the masses of fibres rather than the reduction by tearing of the individual lengths. In use the drum is enclosed within a cast iron cover to prevent splashing.

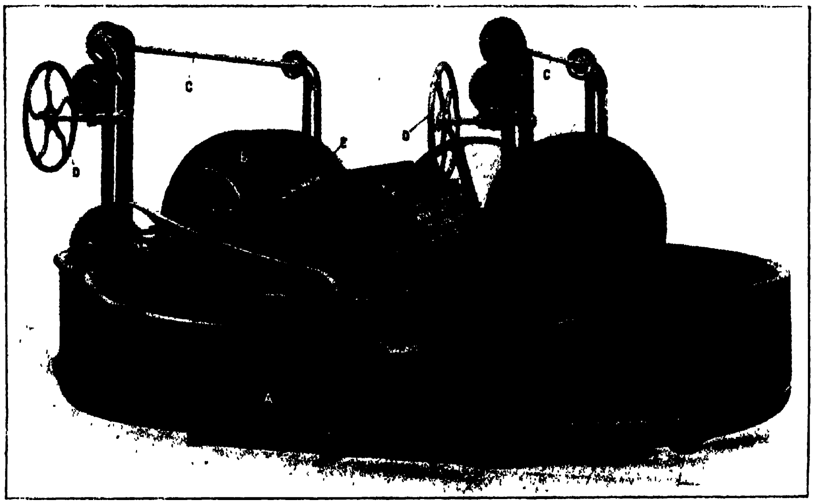


Fig. 14.—James Bertram's Grass Breaking and Washing Engine.

The drum not only acts for opening out the fibrous masses but also serves as the means whereby the mixture of water and fibre is circulated round the vat. This it does by lifting the mixture and throwing it over to the other side of the back fall.

On the far side of the mid feather, that is, over the horizontal portion of the vat floor, two washing drums are mounted on shafts driven by belt and gearing from the end of the breaker drum shaft. The sides of the drums are of wood. Their peripheries are formed of fine wire cloth supported on a perforated backing. The wire cloth allows water to pass through into the interior of the drums, but holds back the fibres. The vertical position of the washing drums has to be carefully adjusted to secure their proper action. For this purpose their shafts are hung between guides from chains attached to pulleys on the overhead shafts C. The hand wheels D afford the necessary means of raising or lowering the drum shafts. The interior arrangement of each washing drum consists of a series of six or so curved paddle blades—the back of one can be seen at E—which conduct the water to a central orifice, through which it is discharged to waste. It is frequently the practice to make the mid feather in the form of a long, narrow box with an open top and a suitable outlet connection, and to discharge the washing water from the eyes of the drums into this.

In use fresh, clean water is continuously added to the fibre in the vat through a pipe situated at one end of the tank. The washing drums rotate at a considerably slower rate than the breaking drum and just dip into the aqueous substance. They remove the dirty water at the same rate as that at which clean water is being added. When the last trace of caustic soda has been removed from the fibre and when breaking is complete, the charge can be drained off through an outlet in the bottom of the vat and sent into a separate bleaching engine. Alternatively it may be bleached in the breaking engine itself. For this method of working the washing drums are raised clear of the charge. The bleaching liquor is then poured into the vat and the whole kept in circulation for the required length of time by means of the breaking drum. On completion of the bleaching period the washing drums are lowered again and the fibre is washed free of chemicals and other impurities in the same manner as before. This engine, it will be seen, can thus take in boiled contaminated fibre and convert it into a clean, bleached and opened-out condition, which only requires the removal of some of its water to be ready for the beating engine.

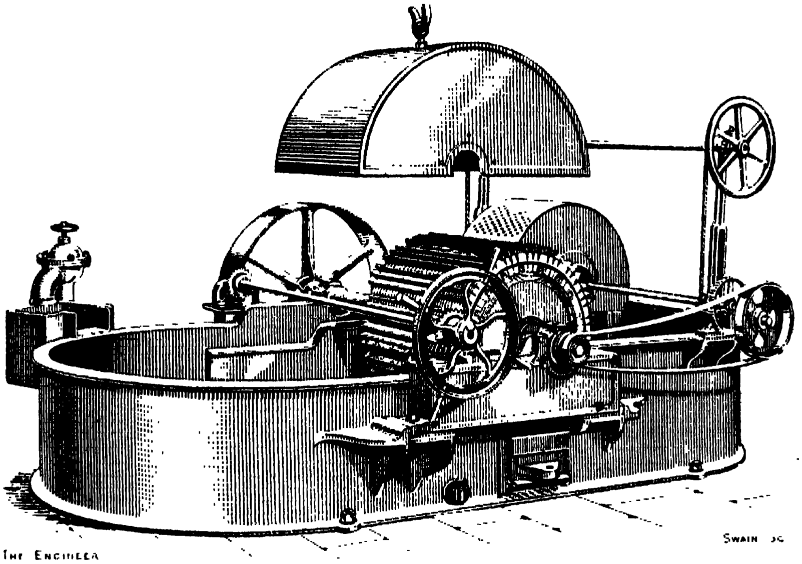
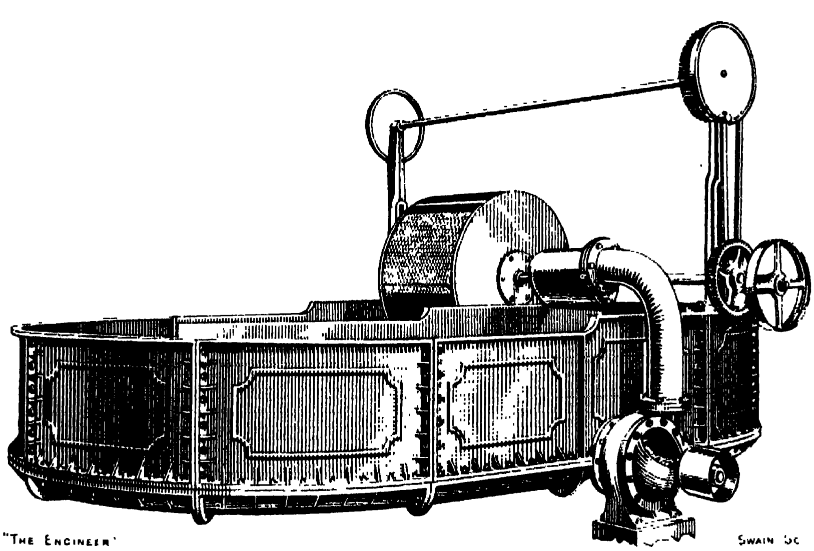


FIG. 15.—Rag Breaking and Washing Engine.

It is perhaps not very usual to have two washing drums fitted to an engine of this description. The commoner form is that illustrated in Fig. 15. This latter engine is for breaking, washing and, if desired, bleaching rags and similar materials. The vat in this case is a solid iron casting, but otherwise the principle of construction is similar to that of the engine already dealt with. The illustration shows the hollow construction of the mid feather and the inlet pipe for the washing water. The charge circulates from the back to the front of the mid feather round the left-hand end.

As we have said, it is a common practice to carry out the bleaching process in a separate machine. It is no doubt economical in power to do so, although the output for the floor space occupied is not necessarily increased. During bleaching the stuff has to be kept merely in circulation round the vat. The breaking drum has, however, to break the fibrous masses as well as circulate the stuff, and cannot, therefore, be designed solely with a view to its efficiency as a circulating means. Indeed, the two requirements are apt to prove conflicting, as the presence of the knives on the bed-plate requisite for one function is a drawback for the other.

A separate bleaching machine known as Cornett's patented mixing and bleaching engine, and, like the two preceding engines, made by James Bertram and Son, of Edinburgh, is illustrated in Fig. 16. The vat in this case is built in sections and can be provided to hold from 15 cwt. to 30 cwt. of aqueous material. It is made with a back fall as before, but has neither a knife drum nor a bed-plate. Instead, the mixture of fibre water and bleaching solution is drawn by a special design of centrifugal pump from the bottom of the vat on one side of the back fall and is discharged through the pipe and muff-like orifice shown over the other side. This circulation secures a thorough mixing of the bleach with the fibre. After bleaching is completed the washing drum shown in the engraving can be brought into use. It will be noticed that in this case the mid feather is solid. The dirty water is discharged from the drum over the far side of the vat. The drum shaft is suspended, not by chains, but by means of connecting-rods hung from two crank discs. It will be understood that in this and the two preceding engines the raising of the washing drum to a sufficient height brings the driving gear wheel automatically out of mesh with its pinion and interrupts the transmission of power, as is required.



"THE ENGINEER" SWAIN SC

FIG. 16. Cornett's Mixing and Bleaching Engine.

Where a separate bleaching engine provided with washing means, such as the above, is in use the previous process of breaking need not necessarily be performed in an engine of the hollander type. That type is excellent as a means of carrying on breaking and washing simultaneously. But as a breaking engine only it is perhaps somewhat extravagant of power. A simpler type of machine for this purpose, known as Cornett's patented cone breaker and made by Messrs. James Bertram, is illustrated in Fig. 17. It consists of a four-part, circular, conical, cast iron casing containing a four-sided conical rotor. Four rows of square steel teeth are fixed inside the casing so as to stagger with four similar rows on the rotor. The stuff as delivered from the boiler is fed into the machine through the hopper at the small end, and after being churned up by the teeth finds its way to an orifice situated in the large end cover, whence it is delivered into a receiving box.

While this machine, in conjunction with Cornett's mixing and bleaching engine, is suitable for treating grass and other fibres, it probably receives more frequent application for dealing with wood pulp, as will be understood later. It is also in considerable use for macerating a second kind of half-made raw material, known by papermakers as "broke." This is simply old waste paper collected from any source, clean trimmings and other scrap stuff from the mills' own cutting machines and similar material. It may include even wood shavings. The engine illustrated is the standard size of machine usually adopted. It has an outer casing about 6 ft. long, the diameters at the ends being 2 ft. 1 in. and 3 ft. 3 in. The output of reduced "broke" obtainable from it is from 8 cwt. to 10 cwt. per hour. A larger size is made capable of dealing with an output of about a ton per hour.

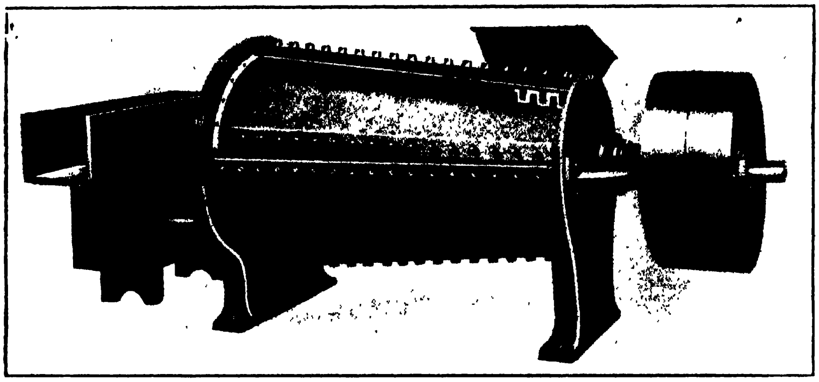
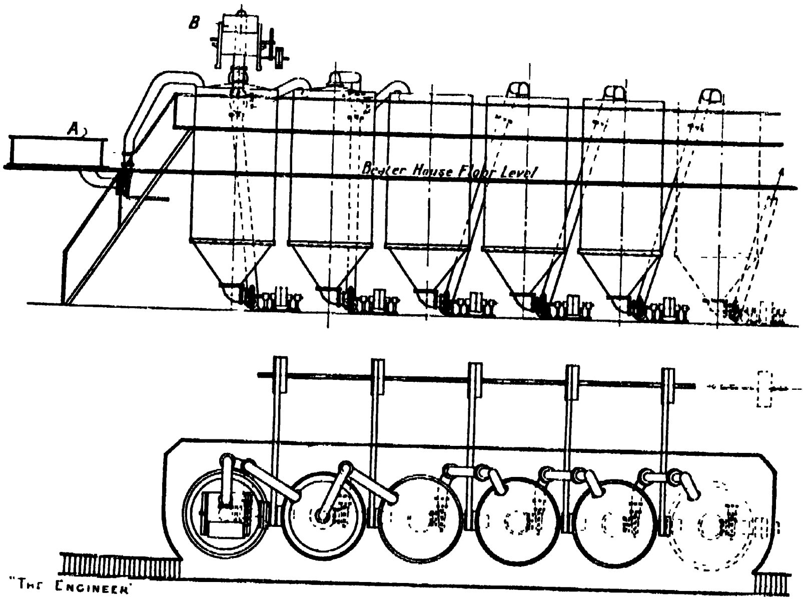


FIG. 17.—Cornett's Cone Breaker- James Bertram.

When the bleaching process is conducted in an engine of the general type described above, the pulp has of necessity to be fairly liquid. If the stuff is thickly concentrated it cannot be circulated efficiently in the flat-shaped vessel of the potcher. Yet unless it is so concentrated the excess of water dilutes the bleaching solution and therefore results in considerable waste. Efforts have accordingly been made to dispense with the use of the potching engine and to devise means whereby the pulp can be bleached when in a highly concentrated state.

With this object in view what is known as the bleaching tower system has been evolved. An example of the apparatus used in this system as constructed, under patents, by Masson, Scott and Co., Limited, of Fulham, S.W., is illustrated in Fig. 18. In this instance we have a battery of five or six towers 8 ft. 6 in. or so in diameter and about 15 ft. in height, each ending in a conical bottom to which the suction branch of a circulating pump is attached. From the washing or breaking engine A the diluted "half-stuff" is lifted by a circulating pump into the first tower. The pump at the foot of this tower lifts the stuff up to a concentrator B, from which it is discharged back into the tower. The construction of the concentrator will not be described at this point, as it is the same as that of a concentrator to be hereafter referred to. For the time being it is sufficient to note that its duty is to get rid of a large quantity of the loose water contained in the stuff.

When a sufficient charge of concentrated stuff has been accumulated in the first tower, the valve indicated between the pump and the concentrator is moved and the whole charge is sent over into the second tower, leaving the first tower ready to receive a fresh charge. In the second tower the stuff is circulated from the foot, over a conical hood at the top, and back into the tower. During this process the bleaching solution is added, the circulation being continued until the solution is thoroughly mixed with the pulp. By this time the second tower is required for the fresh charge which has been concentrated in the first tower. Its contents are therefore passed along into the third tower, and are kept there until this tower in turn is required by the succeeding charge. And so on until the last tower is reached. Each time the stuff is turned over the circulating pump incidentally mixes it up thoroughly, thus ensuring a uniformity of its properties. On reaching the last tower the pulp has become completely bleached. Although not so shown in the engraving, the last tower is fitted with the same circulating arrangements as the second. By means of this the stuff is circulated through the tower while washing water is added to it. Having been thoroughly freed from the bleaching chemicals in this manner—the action may be assisted by the addition to the washing water of an "anti-chlor" such as sodium chloride—the stuff is sent to a second concentrator, whereby the washing water is removed from it. Alternatively, under an older style of working, it may be sent to a "presse pâte," a machine, as mentioned above, serving the same purpose as the concentrator and now largely displaced by the latter.



"The Engineer" Swain Sc.

FIG. 18.- The Bleaching Tower System—Masson, Scott & Co.

We are informed by Messrs. Masson, Scott that over 120 of these tower systems are at work in this country. Not only is a saving of bleaching material amounting to from 25 to 30 per cent. claimed for this method of working, but it is pointed out that as only one circulating pump is in use at a time the power absorbed is very small, much less, indeed, than is required to drive a potching engine. In addition, the stuff has not to be handled by the workers from start to finish, and the bleaching can be conducted efficiently without heating the pulp, as is sometimes done, thereby, it is claimed, saving steam and securing a strong fibre. The installation illustrated in Fig. 18 is capable, we are informed, of dealing with 60 to 70 tons of stuff, as measured in finished paper, per week.

The preparation of the bleach liquor is a matter requiring some attention both from the chemist and the engineer. Bleaching powder in the dried state may be regarded as a mixture—it seems really to be a chemical compound—of calcium hypochlorite and calcium chloride. It is prepared by causing slaked lime to absorb chlorine gas, and should be looked upon simply as a convenient means of handling and using chlorine. When treated with water its two constituents, the hypochlorite and chloride separate from one another and dissolve. If this solution is treated with acid free chlorine is evolved. Such treatment is sometimes resorted to in the bleaching of pulps, as it hastens the action. In general, however, the solution by itself is used, as the addition of acid is thought not to improve the quality of the pulp. The chlorine may be regarded as being but loosely attached to the lime. Its bleaching properties when so attached are not very much less than when it is liberated from the lime by the addition of acid.

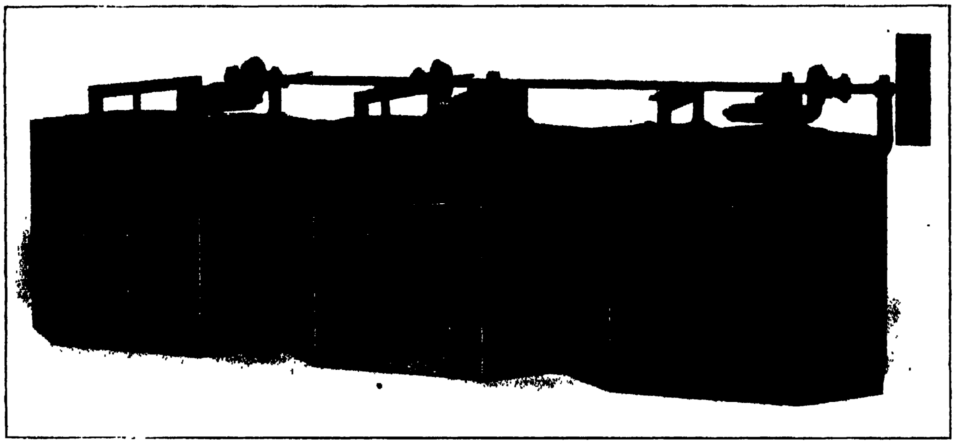


FIG. 19.—Bleach Mixers.

When commercial bleaching powder is dissolved in water the result is a clear solution and a sludge consisting of excess free lime and certain insoluble matters. The chief difficulties to be overcome in the preparation of the bleach liquor are the prevention of waste arising from the incomplete solution of the soluble portions and the attainment of a rapid settling and removal of the sludge.

A typical bleach mixer as made by James Bertram and Son, Limited, of Edinburgh, is shown in Fig. 19. This example consists of three octagonal tanks built up of cast iron plates. Each tank contains two vertical shafts, to which agitating arms are fixed. The lower arms on each pair of shafts lie in the same plane. Their lower edges are not much more than an inch above the bottom of the tank, an important point if the sludge is not to contain an excessive amount of soluble material. All six shafts are driven by gearing from the horizontal shaft shown, but any pair can be thrown out of work by means of a dog clutch.

It is usual to empty the bleaching powder into the agitating tank through a 1 in. mesh sieve and to mix it with water at a temperature of about 70 deg. Fah. The arms are driven at a peripheral speed of about 500 ft. per minute, and are kept revolving for about 20 minutes, at the end of which time the agitator is stopped and the sludge allowed to settle. It is inadvisable to keep up the agitation too long, for after a time it will result in the sludge being reduced to such fine particles that the time lost in waiting for it to settle will outbalance any gain derived from a more thorough extraction of the bleaching elements from the powder. The clear solution is drawn off from the tank at a level which is above the sludge. As shown in Fig. 19, the draw-off pipe contains a flexible portion, and is held up by a chain so that its orifice can be brought to any desired level. The last portions of the sludge take a very long time to settle. In practice the liquor is drawn off before settling is complete. Fresh water is then added to the tank and five minutes or so of agitation given to the liquid. After the second settling the weak liquor is drawn off and may be used as the water of the succeeding batch.

With careful working the bleaching powder lost with the sludge need not exceed 2 per cent. of the original quantity put into the tank. By employing a battery of two or more tanks agitation can be taking place in one while settling is going on in another. The clear bleach liquor is drained off to a storage tank and is thence delivered through a measuring cistern to the bleaching plant.

CHAPTER IV

PURIFYING AND PULPING

WHEN the bleaching process has been completed the material is in the state of being a more or less white, broken-up fibrous substance suspended in water, contaminated with surplus bleaching liquor, and mixed with soluble and insoluble impurities which have been formed by the action of the bleach on the non-cellulose constituents remaining in the material. The care and trouble spent over the removal of the surplus bleach and the other impurities varies very considerably with the quality of paper being made. There are many kinds of paper which do not require a very thorough cleansing process. Indeed, at times no more cleansing will be done than is sufficient to prevent a too rapid destruction of the Fourdrinier wire cloth on which the stuff is converted into a continuous sheet of paper. Corrosion produced at this point by the bleach remaining in the pulp may be said to dictate the lower limit to which the cleansing process is carried. The higher limit is set by considerations relating to the preservation of the paper and the desirability of avoiding its discoloration with the passage of time. If free acid is allowed to remain in the pulp it will in time oxidise the cellulose and this will result not only in turning the paper yellow but possibly in causing it to crumble away. The whole question of the preservation of paper is very complicated and still presents many problems awaiting solution. This much, however, is certain. One of the most important points affecting it is the manner in which the bleaching is carried out and the thoroughness with which the pulp after bleaching is cleansed.

It may be doubted whether once bleach liquor has been added to cellulose fibre it is possible thoroughly to eradicate it and its residues. It is certainly a very difficult matter to accomplish. Doctoring with "anti-chlor" chemicals is sometimes resorted to, but this practice at best is a makeshift and is liable to introduce additional defects of its own. For certain purposes paper guaranteed free from free acid is required—for example, filter paper, paper to be sensitized for photographic purposes, and the very highest class of water-colour paper. To produce this paper the only practicable course seems to be to leave out the bleaching process altogether. Such unbleached paper is made at certain mills. If it is essential to have it white, this result is achieved by the careful selection of the raw material and by washing the pulp for a long time in very pure water.[1]

For ordinary purposes, however, bleaching is resorted to, and, taking the average case, considerable pains are gone to in the subsequent cleansing process. This cleansing process may be said to consist of the straining off of all the loose liquid from the fibrous substance and the washing of the substance subsequently in clean water.

To strain off the loose liquid, or to "purify" the pulp as the process is called, a machine called the "presse pâte" is frequently used, particularly so if the raw material is esparto or other grasslike substance. A presse pâte made by Bertrams Limited, of Edinburgh, is illustrated in Fig. 20. Without anticipating our description of the Fourdrinier machine it is impossible for us to describe the construction and action of a presse pâte, for it is practically identical with what is known as the "wet end" of a Fourdrinier. All we need here say by way of describing its construction is that it consists of a strainer A, a breast box and sluice B, a wire cloth band travelling on a series of small rollers, a pair of deckle straps C, two vacuum boxes D, a pair of couch rolls E, sometimes one or more pairs of press rolls, and an endless felt band F. The bleached stuff is delivered into the strainer and is thence passed on to the wire cloth, where it is converted into a thick sheet of damp paper. It is then passed through the couch rolls and on to the felt band F. Thereafter it may be wound up in a reel on a wooden roller, off which it is taken before further treatment is accorded it.

---

[1] As illustrating the great disparity which can exist in the lasting properties of paper, we may instance the fact that certain paper made in Italy about 1350 is still in existence in a good state of preservation, while some papers made between 1870 and 1880, that is, during the early days of wood pulp, crumble to dust when handled.

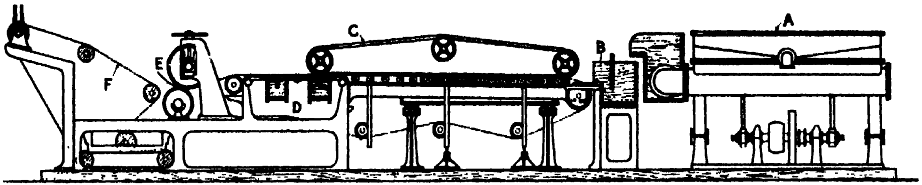
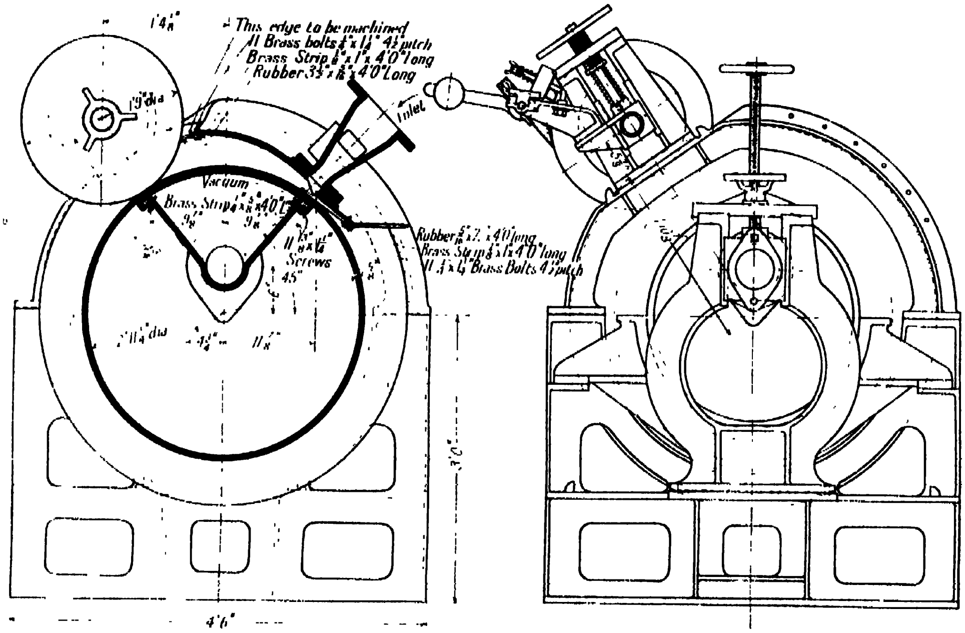


Fig. 20. Presse Pâte Bertrams'.

As a means of concentrating and purifying the "half stuff" between the bleaching and beating processes the presse pâte has been largely superseded by machines known as concentrators. Such machines are much less costly in the first instance, occupy a greatly reduced space, require less power to drive them, and withal produce a better result in so far at least as an increased concentration of the pulp is concerned.

One of the best known of these concentrators is the "Couper." It is made in several forms by several firms. In Fig. 21 we illustrate a Couper concentrator as made by Masson, Scott and Co., Limited, of Fulham. Arranged within a suitable casing is a cylinder made of special acid-resisting bronze and rotated through gearing. The entire surface of the cylinder is perforated and round it is wrapped a fine wire-gauze cloth. The unconcentrated half-stuff is delivered on to this wire cloth through an inlet which is spread out across the full length of the working portion of the cylinder. Just to the right of this inlet the space between the casing and the cylinder surface is sealed by a batten of rubber. Farther round the circumference the casing is broken away to admit a roller known as a "couch roll." This roll is covered with felt and is pressed by adjusting handles against the gauze on the cylinder. Against its side nearest the inlet there presses a rubber batten fixed to the casing. Inside the cylinder a vee-sectioned vacuum box is fixed, the mouth of which is placed under the arc between the inlet and the couch roll. The lips of the box are provided with suitable packing strips. The ends of the box project through the open ends of the casing and are attached to hand screws, whereby the lips of the box may be held in close contact with the interior of the cylinder. Although a pump may be used to maintain the vacuum in this box, this is not essential, as a syphon arrangement is found to provide all the suction that is necessary.

The pulp as it is carried round on the wire gauze across the vacuum box is drained of a considerable quantity of its loose water, and as its passes under the couch roll a farther quantity is squeezed out. At this point it leaves the cylinder and adheres to the felt covering of the couch roll in the form of a damp sheet. A wooden scraper or "doctor" pressing against the couch roll causes the pulp to fall off on to a conveyor or into a storage vessel as desired. The machine illustrated in Fig. 21 is, we are informed, capable of concentrating 5 to 6 tons of pulp per hour as measured after concentration, and requires only about two horse-power to drive it. The degree of concentration effected can be varied slightly and depends upon the quantity of water initially in the pulp. As an example of common practice, we may say that the pulp would contain before concentration equal weights of fibre and moisture. After concentration the water could be reduced by 25 per cent. A greater degree of concentration than this is not aimed at, because if it were attained the stuff would be too thick to pump and beat with ease.



"The Engineer" Swain Sc

Fig. 21. Couper Concentrator – Masson, Scott.

The concentrator is, as we have said, used to remove the excess of liquid from the pulp after bleaching and washing and before beating it. It may be used also before bleaching, as we indicated when describing bleaching towers. It is clear that if the water of the pulp is reduced beforehand by 25 per cent., 25 per cent. less bleaching material will be required to give the standard strength of bleaching solution. After concentration the stuff is first washed again and then beaten. The washing process is conducted either in the same or similar machines as used for washing after boiling, such as we have already described, or is conducted in the beating engine itself, for which purpose this engine would be fitted with a washing drum.

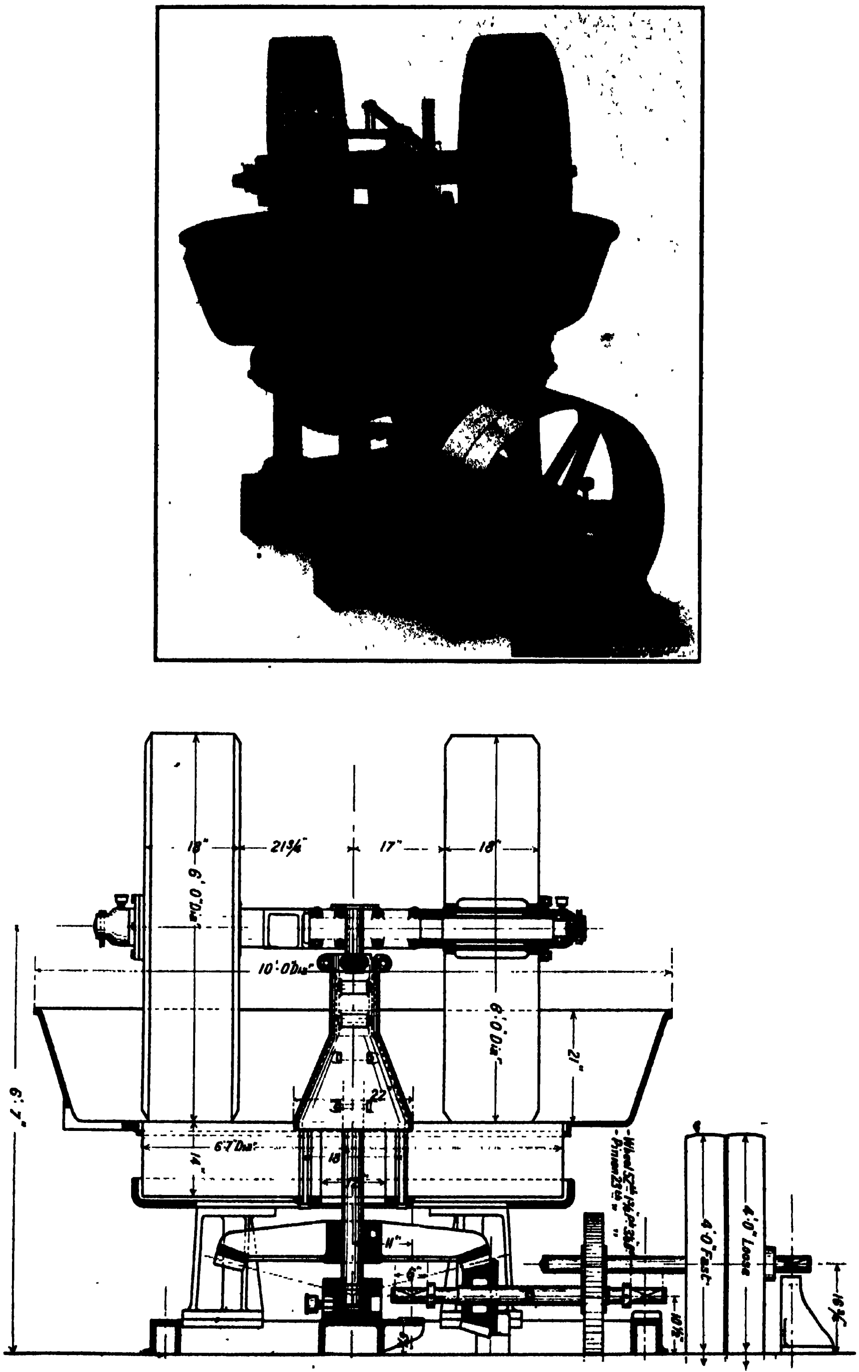
We have now reached the point at which we should commence our description of the important class of machines known as beating engines. It is desirable, however, to reserve these engines for treatment in a separate chapter, particularly so because just at this point an entirely different class of machine demands our attention.

So far we have been describing the machinery used in the production of paper from the original raw material such as cotton or linen rags, esparto or other grass, straw, &c., and the next step in the sequence would be to pass to the beating process. A papermaker, however, has to be prepared at times to deal with old or new waste paper as a semi-raw material. Even if he does not buy this material from outside sources as a settled matter of his routine, he has to face the problem of utilising the considerable amount of trimmings and cuttings of finished paper originating within the mill itself, the defective sheets cast out by the examiners, the broken ends of the webs produced, for example, when a slight hitch occurs in the even driving of the Fourdrinier, the scrapings of unconsolidated fibre taken off the Fourdrinier couch rolls, and so on. These internal sources of "broke," as the papermaker calls his waste stuff, account for a considerable quantity of material in a year's working. That it is economically important to be able to re-make this waste into pulp will be clear if we consider the case of a mill having, say, two machines capable of turning out 50 to 75 tons of paper each per week. The width of the reels of paper produced is, let us say, 100 in. on the average. The reels will probably be slit into three or four sections, and in doing so a strip an inch wide or thereabouts will be trimmed off each of the two original edges. These strips alone thus represent 2 per cent. of the entire output of the mill, and will represent in a year's working 104 to 156 tons or over a week's output of the two machines. The trimmings referred to, as we have said, are but one source of "broke."

The usual method of dealing with broke material is to reduce it to the state of pulp in special machines and then to add this rehabilitated stuff to the regularly produced pulp in the beating engine, so as to secure a thorough mixture of the old and the new. The special machines referred to are of several quite distinct classes. The first we will describe, the edge runner, or "kollergang" as it is usually called in the papermaking industry, is merely an adaptation of a form of machine used for many purposes as widely separated as the mixing of mortar and the manufacture of sweets and chocolates. The second, and perhaps most generally used class, is the "pulper," in which the maceration is produced by revolving prong-like arms. A third variety is the disintegrator, in which the paper is rubbed against a stud-covered surface. A fourth type is the kneader, in which the reduction is effected by two counter-revolving shafts carrying propeller-like arms.

An edge runner or "kollergang" as made by James Milne and Son, Limited, of Edinburgh, is illustrated in Figs. 22 and 23. The example shown is of medium size, the machine being made both larger and smaller. It consists of a stationary circular base of red granite surrounded by a cast iron trough or basin, and two red granite runners journalled at the ends of a horizontal rotating shaft. This shaft is fixed to a central vertical shaft driven by gearing in the manner indicated.

The action of the machine depends, of course, upon the fact that the inner edge of each runner is compelled to run round a circle of smaller radius than the outer edge. Since the stones are rigid the motion is not pure rolling except at a section approximately at the centre of each runner. Slipping takes place on either side of this section, so that the motion is a grinding one. At some section of each runner, where the motion is one of pure rolling, there is no grinding action. This is compensated for by placing one runner $4\frac{3}{4}$ in. farther away from the central shaft than the other, thereby making the grinding effect for the two stones nearly uniform over an annular area on the bed stone of radii 17 in. and $39\frac{3}{4}$ in., neglecting the $1\frac{1}{4}$ in. champfer on the edges of the runners. The motion naturally develops an end thrust in the runners, tending to push them outwards off the horizontal shaft. This thrust is taken upon ball bear-



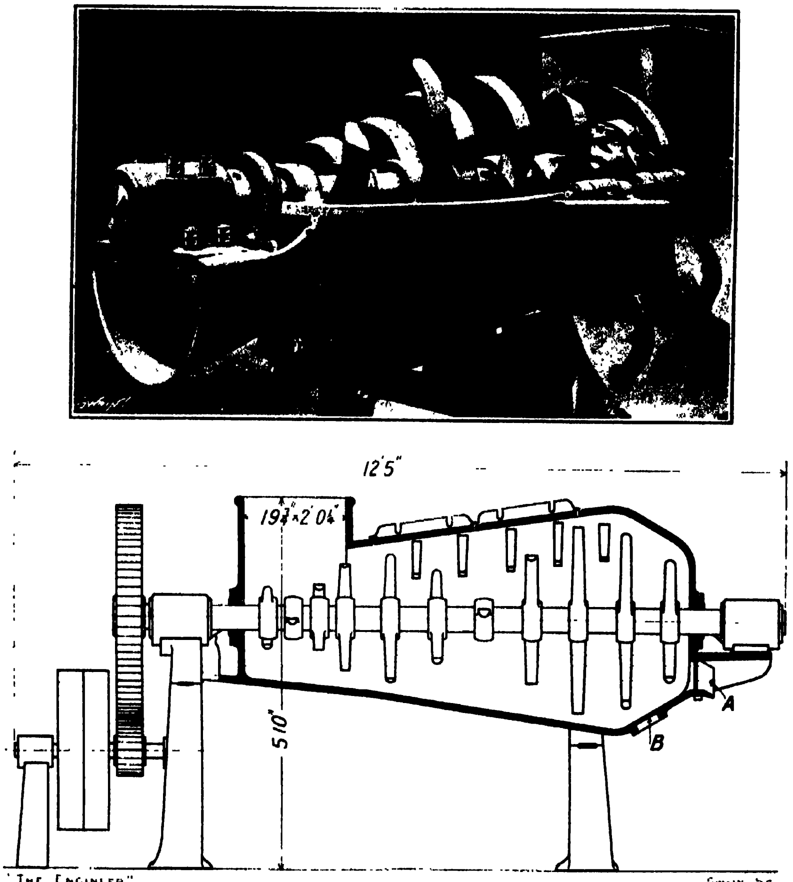
"THE ENGINEER"

SWAIN SC.

FIGS. 22 and 23.—Kollergang—James Milne and Son.

ings. As the stuff being treated may be lumpy in parts, the runners are mounted on cranks on the horizontal shaft, thereby allowing them to rise and fall and so preventing an excessive fluctuation in the power demand.

A small annular area inside the runners and a larger one outside is left untouched by the grinding action. The pulp is not allowed to accumulate in these areas and so escape reduction. It is caught by a scraper mounted on the arms shown in Fig. 22, which rotate with the vertical shaft, and is carried thereby into the grinding area. A somewhat similar scraper on the other side can be lowered into action by means of a handle. When let down it ploughs the material over to an outlet door in the trough side, which door is arranged to be pulled out like the drawer of a desk. To permit of ready access for repair and cleaning, the bearings for the horizontal and vertical shafts are made split, as are the trough and the large bevel wheel and footstep bearing at the lower end of the vertical shaft. There is a speed reduction of about 8½ to 1 between the belt pulley and the vertical shaft. The power consumption varies considerably according to the nature and quantity of the material being treated. We are informed, however, that with the stones running at ten revolutions per minute round the vertical shaft the consumption does not exceed 15 horse-power.



"The Engineer" Swain Sc

Figs. 24 and 25.—"Perfect" Pulper—Masson, Scott.

Of the second class of machine—the pulper—there are several modifications on the market. We have chosen for description the "Perfect" pulper as made by Masson, Scott and Co., Limited, under the patent of A. van Hemelryk. This machine is illustrated in Figs. 24 and 25, and may for most purposes be regarded as typical of all other pulpers.

It is urged against the kollergang that it crushes up with the pulp any foreign material that may be present in the original substance, to the detriment, of course, of the resulting paper. This is particularly a source of trouble when re-pulping old paper, for in this there are often portions of string, tin, wire, &c. The action of the pulper is intended to disintegrate the material by rubbing alone. It is claimed that it separates the fibres without breaking them, and that any foreign matter originally present leaves the machine in an unaltered form.

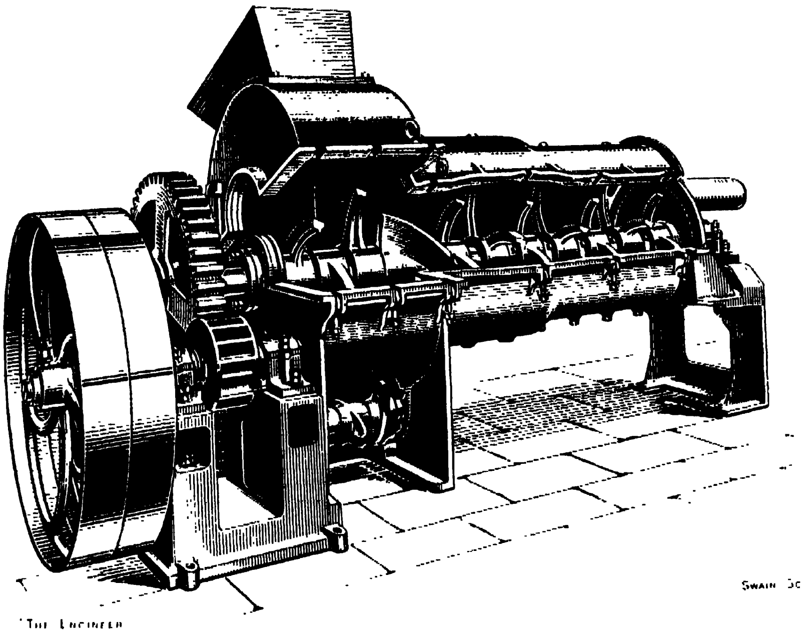


Fig. 26. "Watford" Pulper—Watford Engineering Works.

The pulper consists of a conical cast iron casing containing a central shaft, on which are keyed several cast steel double sickle-shaped blades. The upper portion of the casing has several similar blades fixed to it. The latter blades are curved oppositely to those on the shaft and usually have squared-off points instead of being brought to an edge, as are the others. The material to be pulped is fed into a hopper situated at the smaller end of the casing along with a considerable quantity of water. The shaft is rotated at about 50 revolutions per minute. The fact that the casing is conical ensures automatically that the material will be worked down to the larger end. Here it is discharged over a mouth A—Fig. 25—the opening in which can be regulated so as to control the time for which the material is kept in the machine. At the beginning of the process the unsoftened material is engaged by the shortest arms and is gradually worked down to the longest arms. This feature, it is said, incidentally economises the power required to drive the machine. The object of the arms is not to cut the material up into small pieces but to catch it and rub it against itself and the walls of the casing and so disintegrate it.

In the case of the machine illustrated, the top portion of the casing is in sections, and these are hinged to the lower portion, which is in one piece. A cleaning door is provided at B. These features greatly assist in the washing out of the machine when raw material of one kind has to be changed for another. It may be noticed, too, that the bearings for the central shaft are placed well outside the casing, the idea being to prevent all ingress of lubricating oil to the interior.

A second type of pulper—the Watford, made by the Watford Engineering Works, Limited—is illustrated in Fig. 26. It is similar to the machine described above in that the pulping is effected by means of curved steel arms on a central shaft working in conjunction with two series of square-pointed prongs fixed to the interior of the casing. It differs, however, in the provision at the left-hand end of the pulping chamber of an enlarged drum-shaped space known as the steeping chamber. The central shaft passes through the chamber and here also carries some curved steel arms. Between the two sets of arms, and on the same shaft, is fixed a two-bladed propeller. Above the arms in the steeping chamber a hopper is provided on the casing for the inlet of the material to be pulped. Beneath them is a shaft carrying short, round-point arms, and revolving at a lesser rate than the main shaft. Provision is made for admitting steam and hot water at the base of the steeping chamber.

In the steeping chamber the material is softened and receives a preliminary breaking up. The slow-speed "hog shaft" is intended to prevent the material packing into the foot of the chamber and to collect any strings, &c., with which it is at times almost sure to be encumbered. The propeller then carries the stuff into the pulping chamber, where its reduction is gradually completed. It is delivered out of the casing through an orifice situated above the central shaft.

The power absorbed by a pulper can be very great. It varies, of course, with the nature of the material being pulped, for obviously if this material is in the nature of old cardboard the power required will be greater than if it is, say, old newspaper.

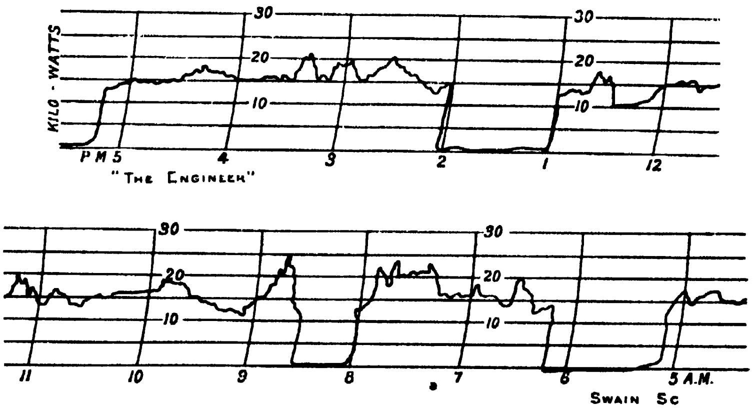


FIG. 27.—Power Consumption of "Watford" Pulper.

For the Watford pulper it may be anything from 20 to 40 horse-power. This, it is pointed out, is less than it would be if the hog-shaft were omitted and the stuff were allowed to pack at the foot of the steeping chamber. In Fig. 27 we reproduce a 12-hour power consumption diagram taken from an electrically driven "Watford" pulper when working on hard sized waste paper. It will be seen that during the spells of working the consumption varied very considerably, in one instance being about 33 horse-power, falling half an hour or so later to about 16. The fluctuations naturally depend on the times and amount of feeding and discharge.

A third variety of "broke" reducing machine is the disintegrator. Of this an example known as the "Partington" disintegrator and made by the Glossop Ironworks Company, Limited, Glossop, is illustrated in Figs. 28 and 29. The moving part of this machine consists of a revolving cast iron cylindrical barrel with closed ends and carrying on its surface eight or so rows of inserted cast iron, steel or bronze teeth. This barrel rotates within a cast iron casing, which is built up of sections bolted together and numbering, in the example shown, eight circumferentially and four longitudinally. In each strake four of the sections are provided with pointed teeth or studs, while the alternate four are provided with sloping bars or "tynes," forming, as it were, an interrupted thread from one end of the casing to the other. Suitable charging and discharging orifices are formed on the upper portion of the casing. During the rotation of the barrel the broke paper is disintegrated against the studs and is fed forwards towards the delivery end by the action of the tyne bars. A pipe across the top of the machine permits a spray of water to be directed on to the paper as it passes through the inlet orifice and also at two points along the casing.

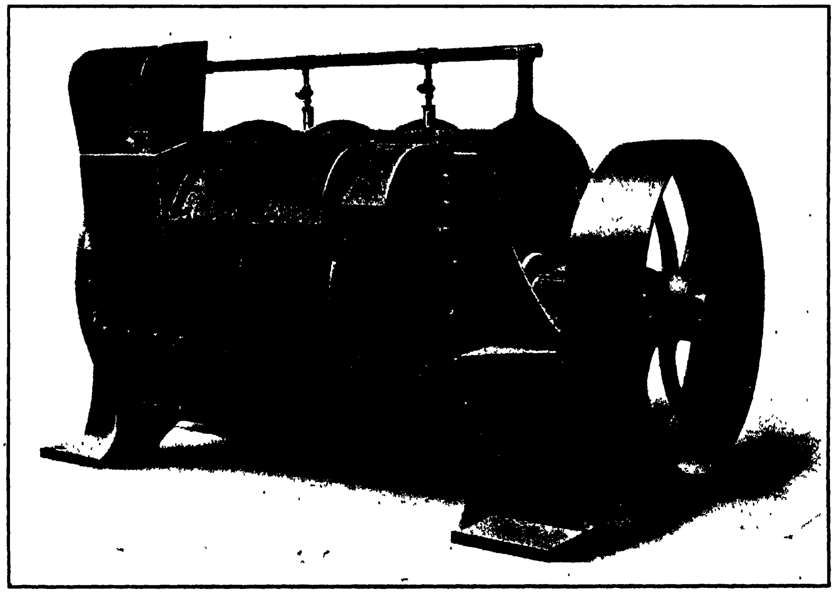
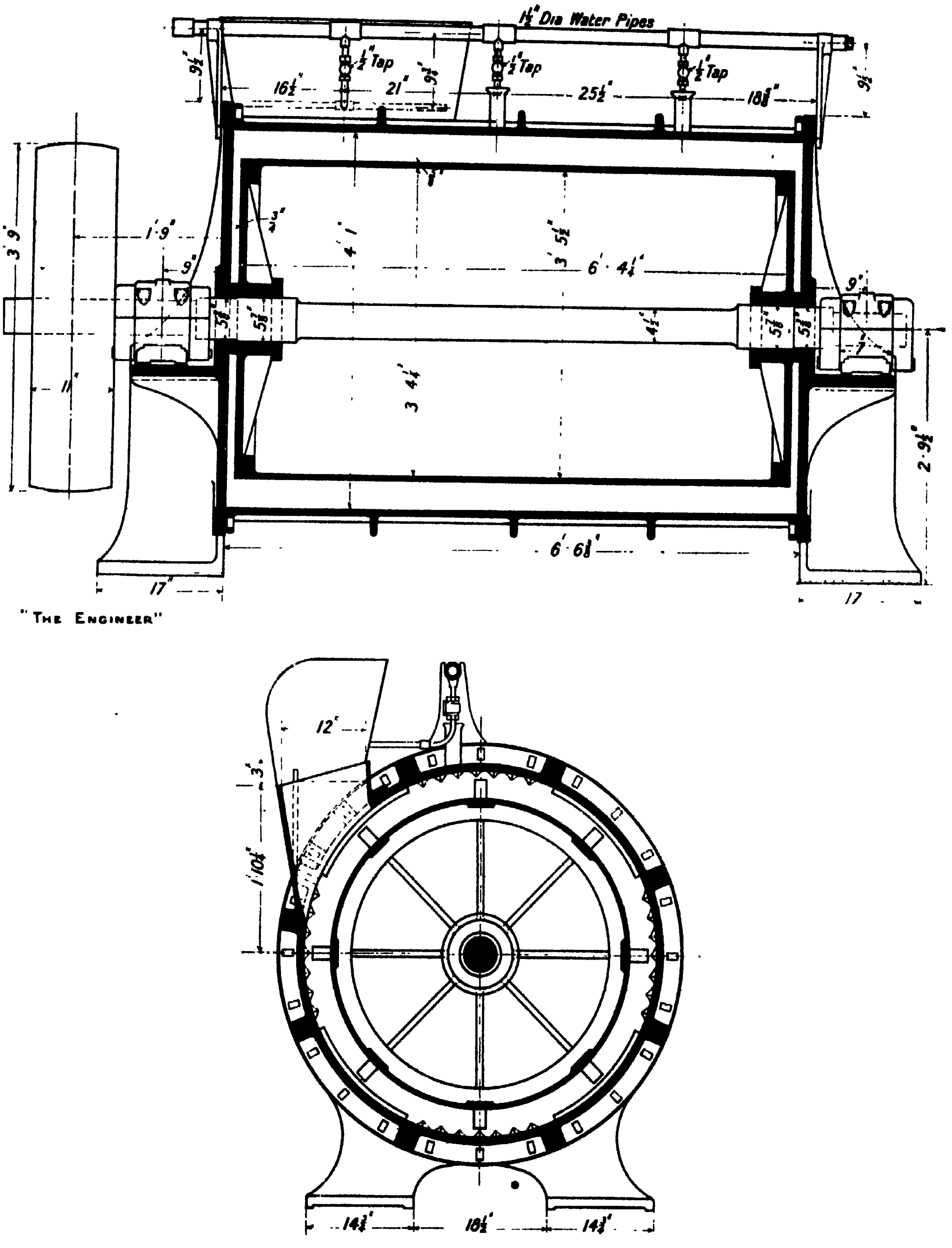


FIG. 28.—"Partington" Disintegrator—Glossop Ironworks.

Of the fourth variety of pulping machine—the kneader—we illustrate an example built by Bertrams Limited, in Fig. 30. The casing of this machine is of cast iron and is made usually in two sections, although three are sometimes used. As shown in the view of the interior—Fig. 31—the sides of the casing are arranged to be turned down on hinges so as to permit of the interior being readily cleaned. Through the casing pass two square-sectioned steel or wrought iron spindles provided with cylindrical portions at the ends to fit within stuffing-boxes. The spindles are connected



"The Engineer"

Swain Sc.

Fig. 29.—"Partington" Disintegrator.

by external gear wheels at one end, and, looked at from above, revolve towards one another. Each carries a series of four-bladed cast iron "propellers." In the first half of the casing the propeller blades have zero pitch. The walls of the casing at this part are plain. The paper, accompanied by about three times its weight of hot water, is fed into this portion through a wooden hopper and is here churned up and softened. Towards the end of the section the propeller blades are of a slightly modified shape, just sufficiently so to propel the stuff forward into the second section, wherein the kneading or reduction proper is effected.

Throughout both sections the two sets of propeller blades intercomb with one another, but in the second section the blades are shaped to give a fast or slow forward movement to the pulp as may be required. In addition the walls of the casing are here provided with heavy internal ribs which tend to hold the pulp back, and in conjunction with the rotating blades secure the kneading action. If necessary, a third section similar to the second is added.

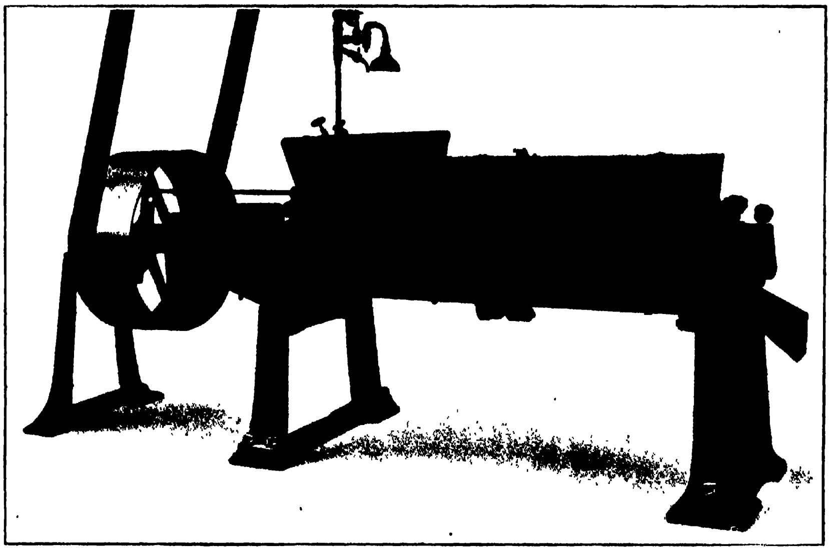


FIG. 30.—Kneader—Bertrams'.

This type of machine is made in various sizes. The varieties in commonest use are those known as the 4 cwt. and the 6 cwt. sizes. These figures indicate the quantity of hard-sized paper that can be re-pulped in the machines respectively in an hour's working. If the paper to be treated is soft and unsized, the output is approximately doubled. In both sizes the propeller shafts should run at 120 to 160 revolutions per minute. The power consumed cannot be stated very exactly, for it altogether depends upon the way in which the machine is operated. If the paper is properly moistened —say, with three times its own weight of hot water—and if a capable operator is employed to feed it into the hopper, the 4 cwt. size of machine can, we understand, be driven with 30 to 40 horse-power and the 6 cwt. size with 45 to 60.

Several advantages are claimed for the kneader. Thus the fibres of the broke paper are, under its rubbing action, neither shortened, crushed nor beaten. The colour, sizing and loading, too, remain unaltered, provided water which is warm is used rather than boiling water or steam, either of which is apt to "cook" the pulp and affect the colouring and sizing and in addition react on the state of beating. For some papers the colouring material used is affected by contact with iron. To deal with these papers the kneader is made—in the 4 cwt. size—with its trough and blades of brass or zinc. In the case of hard-sized papers the re-pulped material, after passing through the kneader, requires beating for only ten to fifteen minutes. Common papers and even boards after being kneaded may not require any beating at all.

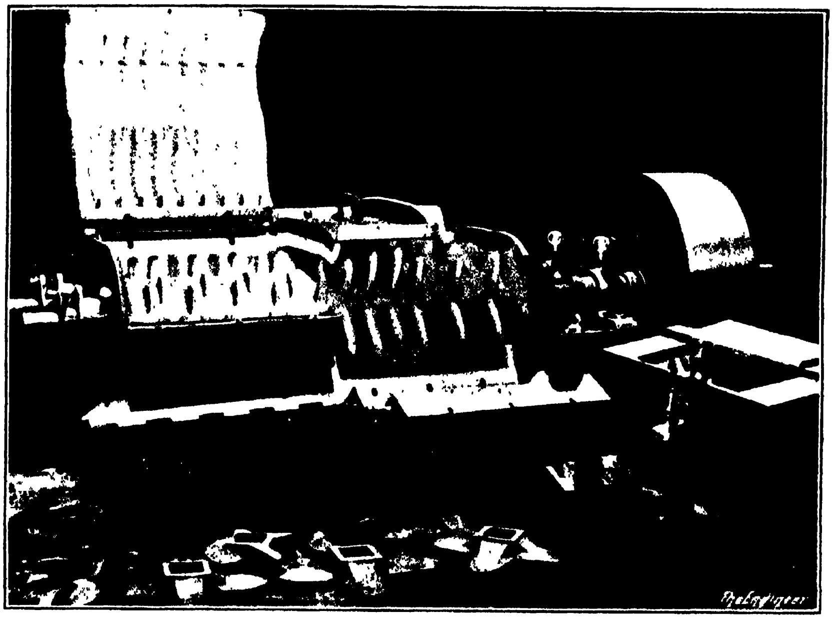


FIG. 31.—Kneader, Inside—Bertrams'.

CHAPTER V

BEATING

THE process of beating is undoubtedly the most important one in the series involved in the preparation of the pulp. It is a common saying that the paper is made in the beater. It is certain that no other machine employed by papermakers has received more attention at the hands of inventors than this one. After 250 years from its introduction, however, the beating engine employed in many paper mills is very little different from the original hollander.

An example of this simple type of beating engine as made by James Bertram and Son, Limited, is illustrated in Fig. 32. It is provided with a knife drum, bed-plate, back fall, and mid feather, just like the breaking and washing engines previously described. The only noticeable difference lies in the greater number of blades on the drum, and the fact that they are grouped in sets of three. Yet its function, as we have already explained, is materially different. It has to reduce the lengths of the individual fibres by tearing them. This result is obtained entirely by the setting of the drum knives relatively to the knives on the bed-plate, and by the length of time for which the beating is kept up. Variables affecting the precise result obtained are the degree of sharpness or bluntness of the knives, the speed of the drum, the temperature at which the beating is carried out, the length of time for which it is conducted, and the rate at which the drum is adjusted relatively to the knives on the bed-plate.

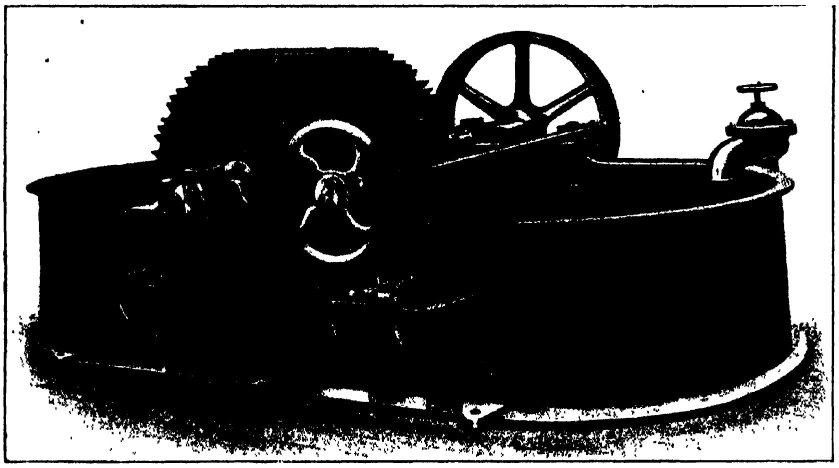
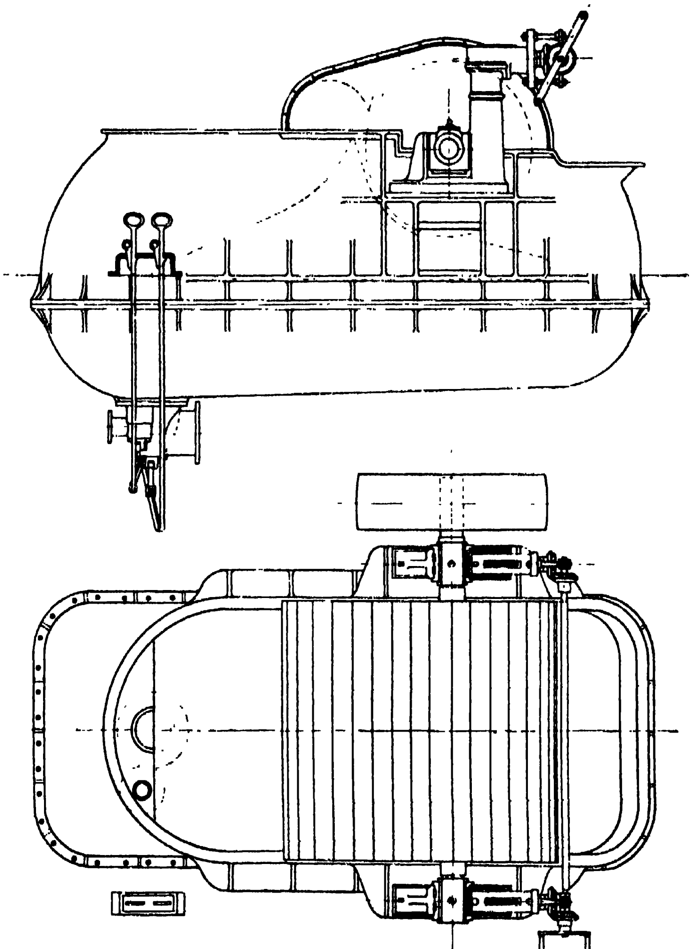


FIG. 32.—Hollander Beating Engine—James Bertram.

Beating is thus a very complex operation, and requires a high degree of skill on the part of the beaterman. It is probably not wholly a mechanical matter. Cellulose is insoluble in water, but with suitable treatment cellulose fibre can be made to assimilate water. Whether or no this assimilation is made to take place, and if so to what degree, are matters under the control of the beaterman, and have a marked effect on the character of the resulting paper. As examples of the various treatments possible, we may say that pulp for blotting paper is beaten quickly with sharp knives. The fibres are thus not allowed to assimilate water, and are cut rather than torn. The result is a weak, absorbent paper, the absorbing powers of which are increased, as we have already explained, by suppressing the sizing materials. If the pulp is beaten slowly with dull knives the fibres are torn and bruised and made to assimilate water. The resulting paper will be hard and dense, strong and semi-transparent.

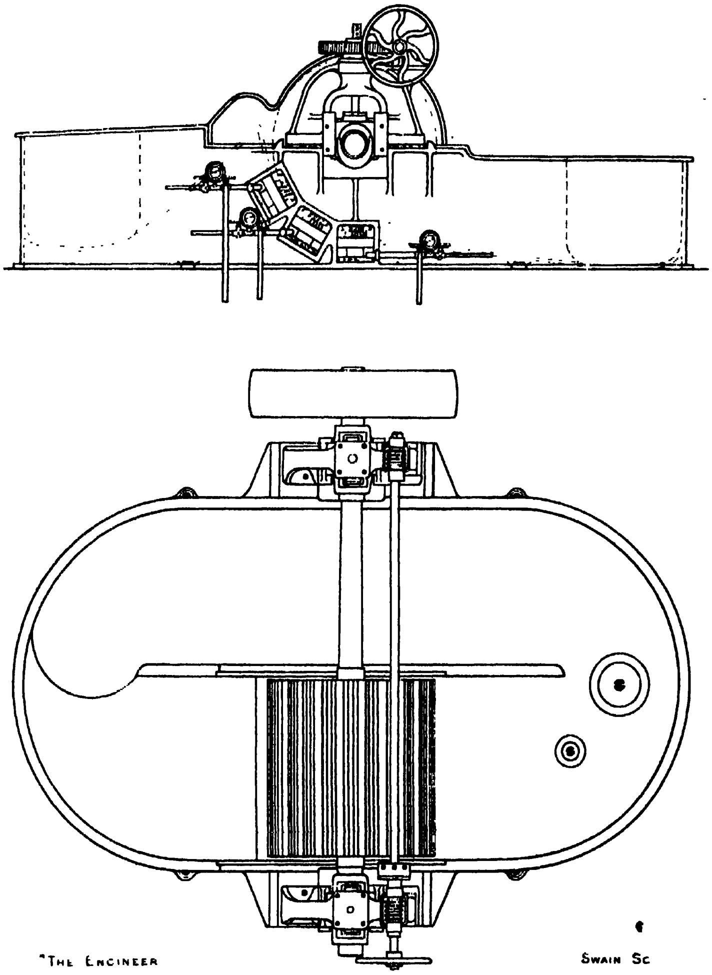


"The Engineer"

Swain Sc.

Fig. 33.—Umpherston Beater.

The exact time for which beating is kept up depends not only on the result desired, but on the nature of the raw material. Obviously the naturally short fibres of esparto grass, straw, and wood will, for instance, be more readily beaten than the naturally long fibres of cotton and flax. Eight hours or more are commonly devoted to the beating of cotton rag pulp, and for special results this time may be considerably increased. In the case of esparto the average time may be set down as about three to four hours. In cases where a blend of, say, cotton rag and esparto pulp is required, each constituent is usually separately beaten for the appropriate time, the blending taking place subsequently in a suitable machine. The whole question of the separate or simultaneous beating of blended materials is, however, still to be thoroughly investigated by papermakers.


"The Engineer

Swain Sc

Fig. 34.—Hollander Beater with Hydraulic Plates.

The first modification of the common type of beating engine with which we will deal is that known after its inventor as the "Umpherston." This engine, introduced so long ago as 1880, is illustrated in an improved form in Fig. 33, and, like the machine already dealt with, is made by James Bertram and Son, Limited. The important difference between this and the old type lies in the form of the vat. Instead of circulating the pulp in a horizontal plane it is circulated in a vertical plane by the provision of a return passage beneath the back fall. The course of this passage as well as the outline of the back fall is indicated in the engraving by dotted lines. For the same beater capacity the floor space occupied by this engine is considerably less than in the old style, and this fact is the chief reason of the design.

The original idea of employing a fixed bed-plate and an adjustable beater roll is still in very common use. Its adoption demands great skill and much experience on the part of the beaterman, for he has to regulate the contact of the roll knives and bed-plate knives by his sense of touch and the sound produced: An inversion of affairs due to Messrs. Caldwell, papermakers, of Inverkeithing, and Mr. John White, a director of James Bertram and Son, Limited, has much to commend it. In Fig. 34 the system is shown as applied to an ordinary hollander type beater and in Fig. 35 to an Umpherston beater.

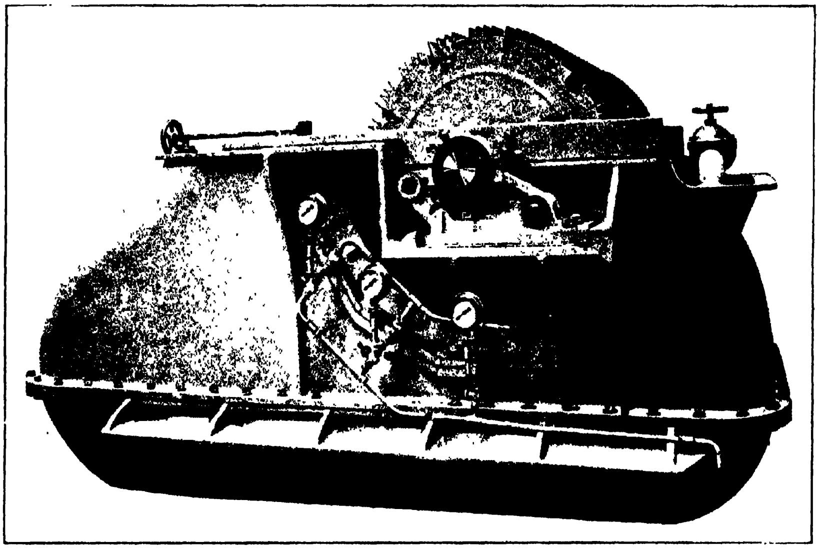


Fig. 35.—Umpherston Beater with Hydraulic Plates.

The beater roll may or may not be fitted with means of vertical adjustment. The feature of the invention lies in the fact that the bed-plate is made in more than one part—three in each case illustrated—and that each part is separately adjustable against the roll knives by hydraulic means. In both engravings, it will be understood, a certain cover-plate has been removed to show the internal arrangement at the bed-plate. Each portion of the bed-plate is provided with a pressure gauge and the necessary hand cocks for controlling the admission and exhaust of the pressure water.

The use of these multiple hydraulic moving plates confers, it is claimed, several important advantages. In the first place it may be pointed out that the reputation of a paper mill for a particular class of paper depends very largely upon the uniformity with which it can turn out this paper, and that this uniformity depends to a marked degree on the personal qualifications of the beaterman—that is, if the old style of hollander is in use. The manner in which the roll is adjusted to begin with and from time to time during the beating process is one of the most important under his control.

With the Caldwell and White system it is easy to keep a record of the pressures applied to each plate and the times of their adjustments, and thus, so it is claimed, give a means of repeating exactly in the future the conditions observed in any successful beating. It need hardly be pointed out that to do so with certainty we must see that other conditions are kept constant. Of these the state of the knives is perhaps the most difficult to regulate.

By using a bed-plate composed of three separately adjustable portions, a wide range of beating conditions can, it is claimed, be obtained. As an example, the first plate can be used for cutting the fibres, and the two others for softening the pulp, or for any other desired manipulation. The power consumed by a beating engine is very considerable. Owing to the presence of the back fall the mere circulation absorbs a great proportion of the power. If, therefore, we can do the same amount of beating for one-third of the amount of circulation, we may expect to find a good saving of power. This is apparently the case, for Messrs. Bertram state that in a mill fitted with Caldwell and White beating engines a saving of 33⅓ per cent. in time and power has been recorded. It may be estimated from this figure that, in an ordinary beating engine, of the power consumed about one-half is spent on circulating the pulp. Another important advantage claimed for this system relates to the life of the knives on the roll and bed-plate. With an ordinary engine the wear of the knives may even after a few weeks' work be found frequently to be very irregular. They may work much harder on one side than on the other. To repair them, therefore, entails a certain loss of metal, and as the blades are usually made of bronze, this may easily result in a fair amount of monetary loss. A worse result, however, arises from the fact that during the circulation of the pulp centrifugal force carries the heavier particles of fibre towards the outside of the vat, that is, if this is of the hollander type. If the roll is bearing hardest at its inner edge, this entails the risk of the pulp being unequally beaten. With the hydraulic plate system the pressure is distributed equally and the bars are kept in uniform contact throughout their length. The pulp produced, it is said, is beaten sufficiently equally to make the subsequent use of a refining engine unnecessary.

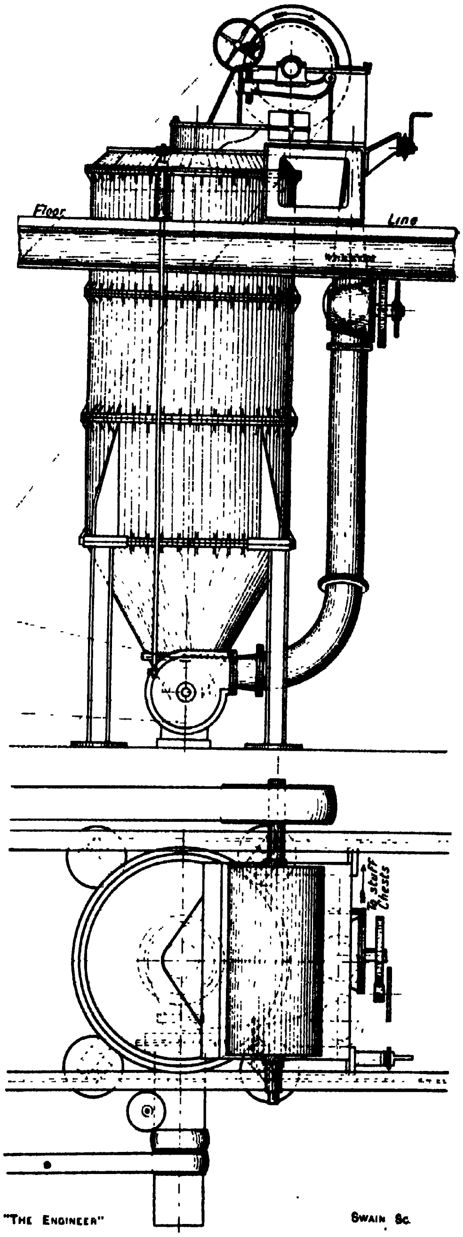
We understand that the Caldwell and White hydraulic moving plates can be fitted to many existing types of beaters with little trouble or alteration.

The greatest source of trouble in the hollander type of engine is undoubtedly the difficulty of securing the proper circulation of the stuff in the vat. The thicker the stuff is, the greater is this trouble. In the breaking and washing engine the stuff is very liquid, and the difficulty is not particularly acute. But in the beating engine matters are otherwise, for here economy and good results alike dictate the beating of the stuff in as thick a condition as possible. In practice a compromise is made. Something less than the full consistency desired in the stuff is adopted, but the consistency chosen is sufficiently thick to make it necessary to modify the design of the beater roll in order that it may act better as a circulator. The knives have, in fact, to be fewer in number and have to be spaced otherwise than is ideally desired from the point of view of efficient beating.

It is for these reasons that numerous efforts have been made to separate the two functions of the beater roll, that is, to make it serve purely as a beating device and to install some independent means of circulating the pulp. A beater of this class is the tower beater, an example of which as made by Masson, Scott and Co., Limited, of London, is illustrated in Fig. 36. In this there is employed a cast iron circular tower about 6 ft. internal diameter and 11 ft. deep, with a conical bottom, which gives it a total height of about 14 ft.. The cone at the foot is connected to the inlet branch of a centrifugal pump, especially designed to handle stuff of thick consistency. The pump outlet is connected to a vertical external pipe, through which the stuff is raised into the beater casing to be discharged directly into the blades of the beater roll. The beater casing is fixed on top of the tower and from its outlet the pulp falls directly on to a conical baffle-plate situated within the mouth of the latter. The beater roll is adjustable relatively to the bed-plate knives in the usual way. The knives on it, however, are uniformly spaced around its circumference and are considerably more numerous than in the ordinary hollander beating engine. They may, in fact, number 128 as compared with the maximum of 72 on an ordinary roll of the same size.

For every revolution of the beater roll an equivalently greater amount of work is done, and as a result there is a corresponding reduction in the beating time. There is, too, a saving in the power consumption. The actual beating operation probably absorbs the same number of horse-power hours as in the hollander type. The circulation is, however, effected far more efficiently. The pulp naturally tends to rise to the same level roughly in the external pipe as in the vat, and as the vat is worked almost fully charged little effort is needed to throw the stuff up into the beater roll.

Another important advantage of this type of beater lies in the reduced floor space which it occupies, for its greatly increased vat capacity. It is true that it occupies space on two floors, but head room in most mills is far cheaper than floor area. Again, the circulating pump can itself be used to empty the vat quickly at the end of operations and to discharge the pulp through the valve and pipe shown to the storage chests or elsewhere in the mill. In the case of the ordinary hollander a special pump has to be installed for this purpose, or the hollander has to be so situated that the pulp will flow from it by gravity to the required destination. The latter course may easily involve a considerable amount of wasted head room and floor space beneath the engine.



"THE ENGINEER" SWAIN Sc.

FIG. 36.—Tower Beater—Masson, Scott.

The pump itself seems to play an important part in the treatment of the fibrous stuff. The pulp can hardly pass through it without experiencing some mechanical result. Indeed, its action closely approaches that of the refining engines, to be dealt with hereafter, so much that the makers refer to the whole plant as a "tower beating and refining engine."

Another variety of the "circulating" type of beater is the Reed patented engine, an example of which, as made by James Milne and Son, Limited, of Edinburgh, is illustrated in Fig. 37. In this the vat is U-shaped in plan, the floor of one limb falling downwards from the back fall, and the floor of the other being nearly horizontal. Across the ends of the limbs there is situated a trunk containing a power driven screw, by means of which the stuff is raised and shot into the beater roll. The reaction on the screw is taken up on an external ball thrust bearing. As the roll is not used to effect the circulation of the stuff it can be fitted with many more bars than is usual. These may be about 150 in number, and need not be arranged in clumps of three or so. The knives in this roll are generally either of crucible or Bessemer steel, and are usually $\frac{1}{8}$ in. thick. The method of fixing the knives on the roll is indicated in Fig. 38. The roll cylinder is lightly slotted crosswise for the reception of the butt end of the knives. Between each pair a block of mahogany or other wood is carefully inserted to make a tight fit. A wrought iron ring is then shrunk into recesses in the blade and block ends, and this, on contracting, holds the parts firmly together. The blades, we understand, can be worn right down to the iron ring before renewal is necessary if the wood filling is from time to time cut away to give the necessary clearance. The knives on the bed-plate are frequently set at a slight departure from parallelism with the knives on the roll. With the same idea in view, namely, of course, the attainment of a scissors-like action, the bed-plate knives may be arranged in plan as a series of very wide open vee's.

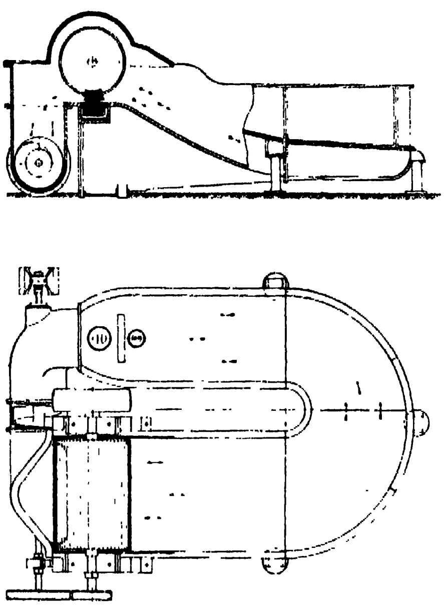


FIG. 37.—Reed Beater—Milne.

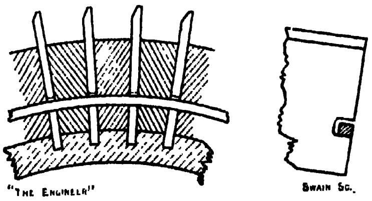
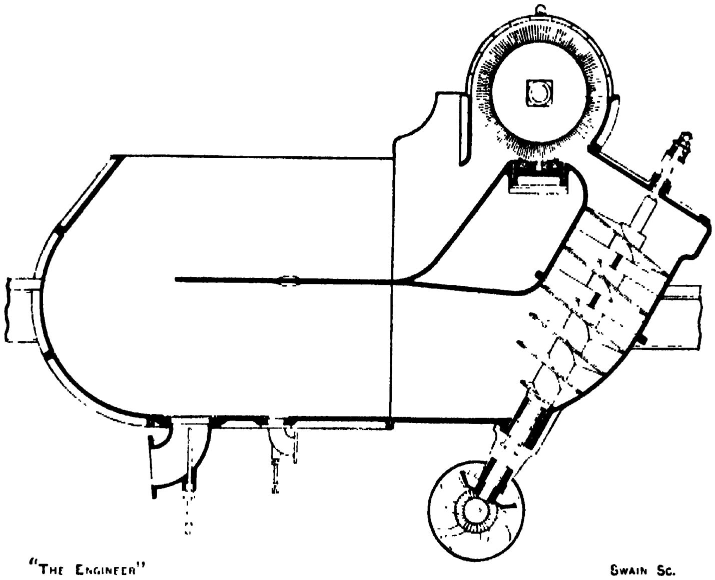


FIG. 38.—Attachment of Blades to Roll.

Of the many other "circulating" beaters which have been invented, we can only deal with one more, the "Acme" beater, as made by Bertrams Limited, of Edinburgh. Simple paddle wheels have been attached to the ordinary hollander for the purpose in view, but it seems to be generally admitted that this plan is not very suitable for short fibre pulp, say that derived from esparto grass or wood, although they seem to be fairly efficient as circulators of long and strong stuff, such as rag pulp.

The "Acme" beater is shown in Figs. 39 and 40. The vat, it will be seen, is somewhat similar to that of the Umpherston beater, already described. The "mid feather," however, is in the form of a plate, which is hinged so that it may be lifted up in order to clean out the bottom of the vat. The circulation is effected by means of an Archimedean screw mounted on an inclined axis in an extension of the vat beneath the roll. The screw is driven from its lower end, and its weight is supported on oil-tight ball thrust bearings.

An ordinary Archimedean screw may be regarded as a very efficient circulator for thick liquid stuff, provided the lift is quite small. As the lift increases the efficiency rapidly falls off, because the stuff begins to rotate with the screw and to flow backwards down it. In the "Acme" beater the lift to be overcome is about 12 in., a height too great for the efficient operation of an ordinary Archimedean screw. The screw adopted is a compound one, being divided into sections—three are shown in Fig. 39—with stationary blades in between. The two top portions do not form continuations of the helical surface of the lower portion. Each is advanced by about half a turn



"The Engineer" Swain Sc.

Fig. 39.—Bertrams' "Acme" Beater.

relatively to the one below it. By these means the rotation of the pulp with the screw is, it is claimed, effectively prevented. A test conducted by Messrs. Bertram may be quoted as indicating the suitability of this form of screw for dealing with thick stuff. It was found possible to force pulp through a 12 in. diameter pipe 18 ft. high when the pulp was so thick that it would not drop out of the pipe when the connections at the lower end were removed. Such pulp is, of course, a good deal thicker than is used in any beater.

Special attention has been paid in the design of this engine so to shape the vat that there is never more than 3 in. depth of pulp above the level of the bed plate. Considerable power, it may be pointed out, can be wasted in driving the roll blades uselessly through the thick pulp if this is allowed to lodge in front of the roll. The capacity of the vat varies from 600 lb. to 1500 lb. of dry paper.

In Fig. 40 we give an external view of an "Acme" beater, which differs from that described above in that it is provided with a washing drum. The construction of this drum is similar to that of the breaking and washing engine drums described in an earlier chapter. Its function is to remove the impurities remaining in the stuff after it has been bleached. It is, perhaps, not very good practice to perform the second washing in the ordinary type of beater, because the beater roll is very inefficient as a circulator. It is, indeed, we believe, by far the commoner practice to wash it in the same engine as used for the first washing. If, however, we do not rely on the beater roll to circulate the stuff, but, as in the " Acme " beater, use a separate circulating device, then nearly all the objections to washing the stuff in the beater vanish. The difficulty remains, however, that while efficient beating requires the stuff to be highly concentrated, washing it necessarily dilutes it. The second washing and the beating should, therefore, be conducted separately rather than simultaneously. The advantage of being able to perform the two operations in the one machine lies in the saving of time and labour otherwise spent in transferring the stuff to an extra machine.

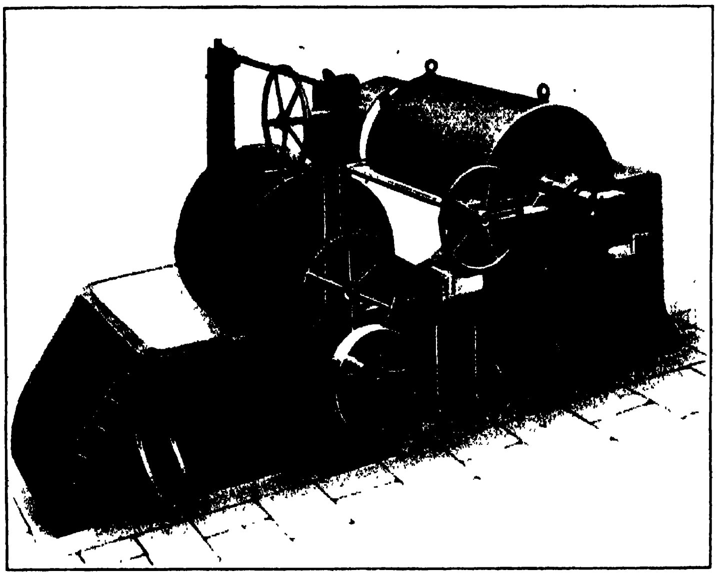
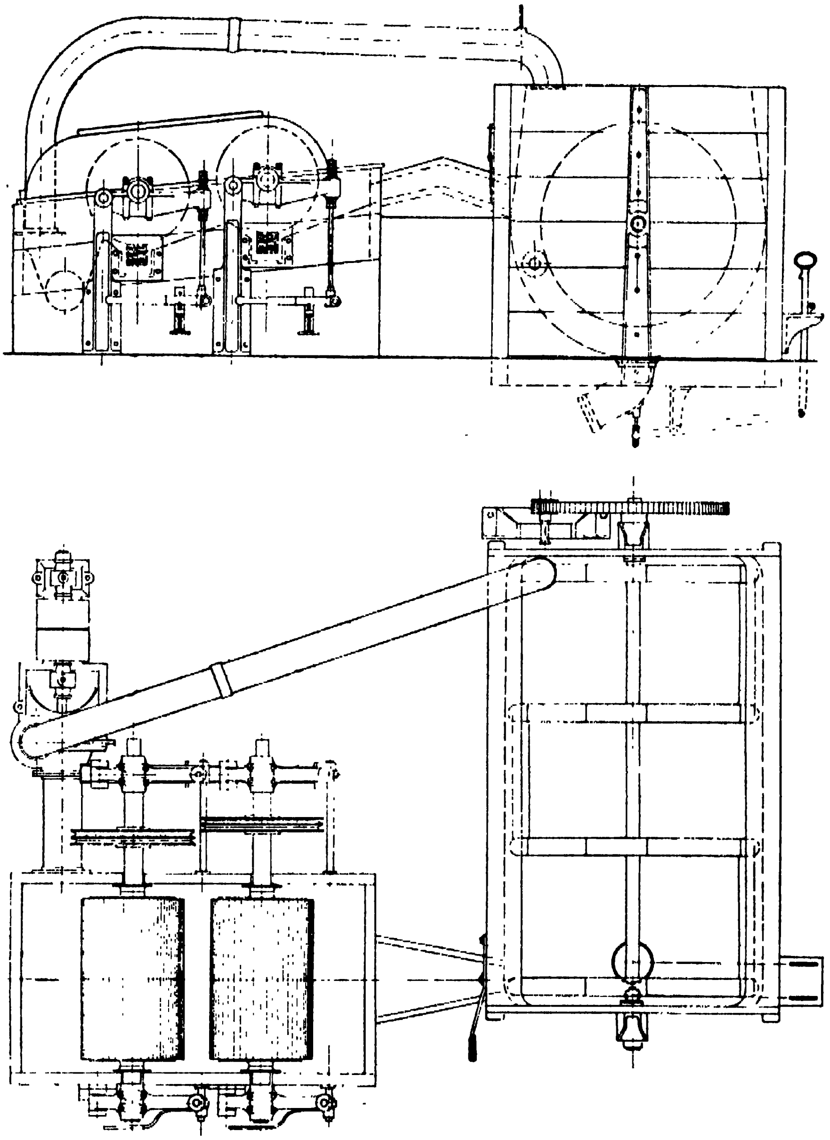


Fig. 40.—"Acme" Beater with Washing Drum.

Many attempts have been made during the last forty years to construct a successful beating engine with more than one roll. Such an engine, it is to be expected, would save both floor space and power, and would considerably hasten the beating process. The chief difficulty to be overcome in the design relates, it would appear, to the adjustment of the rolls. It is urged by certain authorities that unless the rolls are very carefully adjusted one of them will do all the work, so that the other, or others, will merely be encumbrances.

An example of a twin roll beater which, we understand, is in successful operation is illustrated in Fig. 41. This is Nash's patented beating engine, and is made by James Milne and Son, Limited, Edinburgh. The vat is rectangular in plan, and contains two modified back falls and a sump from which the stuff is withdrawn by a centrifugal pump and returned to a main container. This container is provided with power driven revolving agitator arms. A sluice regulates the flow of stuff from the container to the vat, and it is claimed that the action of the rolls is not affected by variations in the depth of stuff in the container. The weight with which the rolls bear upon the dead plate knives can be accurately adjusted by a system of levers which may be fixed and locked in position.



"The Engineer" Swain Sc.

Fig. 41.—Nash's Beater—Milne.

This engine, it is stated, is of particular value for treating mixed pulps composed of long-fibred and short-fibred material. The long-fibred stuff is milled for a suitable length of time before the short-fibred material is added. The mixing is conveniently effected in the agitator. There may be two of these agitators, so that while one is serving the vat the other is receiving and mixing its charge.

CHAPTER VI

REFINING

THE process of refining is very closely associated with that of beating. The machines employed in it have no external resemblance to the hollander type of beater, with its large vat and its back fall. Actually, however, the internal action of a refining engine is of quite the same nature as the action of the beater. In both classes of machine the pulp is scissored between a set of moving and a set of stationary blades.

It will be readily understood that after beating has been carried on for a certain length of time we may have the pulp sufficiently reduced as regards by far the greater bulk of it, although small portions may yet have escaped reduction or, having been reduced, may have felted together in small masses. Such particles cannot be allowed to pass into the paper, so that either of two courses seems open to us. The beating may be carried on farther until all the particles have been reduced or opened out, or the beating may be stopped here and reliance placed on the strainer, through which the pulp is passed just before it flows on to the Fourdrinier wire, to hold back the unreduced particles. The latter course is the better one, although it is open to the objection that unless the straining plates are kept very clean great trouble will ensue from the choking up of the slits by the quantity of unreduced fibre which they will be called upon to hold back. The former course is not practical. To reduce the last few particles in the beater is a difficult matter, for the greater the proportion of the charge already reduced the more difficult is it to catch the remaining portions of unreduced fibre between the blades. Apart from this the course suggested is very wasteful of power. To reduce the last pound or so of the charge we have to continue the circulation of the whole round the vat just as at the commencement of beating. As the power spent in circulating the stuff may be as high as 50 per cent. of the total power absorbed by the machine, it will be seen that the reduction of the last pound in the beater is effected at an exorbitant price.

It is here that the refining engine comes in. Let us imagine that we can transfer the all but completely reduced pulp to a machine capable of exerting a scissors-like action on the pulp just like the beater, but so designed that the portions of the pulp which have been insufficiently reduced are prevented from passing through the blades until they are so reduced, while the remaining portion, already sufficiently reduced, flows straight through the machine away to the storage tank or the Fourdrinier machine. The bulk of the stuff is cleared away at once, and the power spent in reducing the remaining portions is considerably more commensurate with their amount than it would be if the whole were kept in the beater until complete reduction was effected.

This is an outline of the philosophy underlying the use of refining engines. But the matter does not stop here. The reduction of the last pound or so out of a total charge in the beater of, say, 5 to 10 cwt. is not a very important matter economically, provided we have means, such as a strainer, of preventing the unreduced portions passing into the finished paper. Even if the pound or so of material held back by the strainer were wasted—it need not be—the value it represents in a year's working would certainly not pay for the interest on capital, depreciation, attendance, and other charges involved in the attempt to recover it by means of a refining engine.

So long as the full original charge is kept in circulation in the beater vat that proportion of the total power absorbed by the machine which is spent on the circulation is practically constant no matter what stage the beating may have reached. Again, the power spent in driving the roll may be divided into several parts, of which probably all except one remain practically constant, no matter how far the beating has progressed. Thus the power spent against journal and blade friction, and in driving the roll through the pulp on either side of the bed-plates bars—the latter portion may be considerable unless the roll runs but lightly immersed in the pulp—will be, to all intents, constant. The only portion of the power which falls off as the beating proceeds is that spent in the scissoring action of the blades. This, when isolated from the power expended in the rubbing of the sets of blades together, is a very small proportion of the whole. Without attempting to assign correct values to the different items we give in Fig. 42 a self-explanatory diagram, showing roughly how a beater absorbs power. This indicates very clearly the manner in which the horse-power expended per pound of material yet to be reduced increases as the beating proceeds. The point to notice is that at some considerable time before we reach the stage of having only a pound or so of the material yet to reduce, the expenditure of power for the work remaining to be accomplished is highly extravagant.

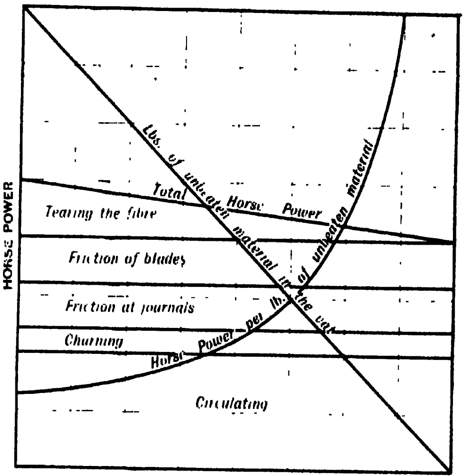


Fig. 42.—Hollander Power Diagram.

Clearly then at some stage, determined by local conditions in certain respects, it pays to stop the beater and transfer the charge to a refining engine, which will immediately cast out the stuff already sufficiently beaten and complete the reduction of the rest. This is an extended use of the refining engine, and is its most important function. The term refining seems hardly applicable to it.

It is easy to see that this use of the refining engine not only saves a considerable amount of power, but also effects an equally great saving in the time spent over the beating process. If we use a refining engine a big part of the charge can be on its way to the Fourdrinier at a time when if no refiner were in use it would still be circulating uselessly round the beater vat. Again, in a beater an unreduced particle between two consecutive passages under the roll has to make a complete round of the vat. In the refiner it is, as it were, kept hovering about the blades until its reduction is completed.

Conditions vary so greatly that we must hesitate in giving a definite figure for the saving of time and power obtained by the use of a refining engine. It may be said, however, that, worked to the best advantage, the addition of a machine of this type may result in a saving of both time and power, separately amounting to from 30 to 60 per cent. of the corresponding figures for a beating engine alone.

A refining engine made by Masson, Scott and Co., Limited, of Fulham, S.W., is illustrated in Fig. 43. It consists of a conical external casing—see Fig. 44—and a conical internal rotor—see Fig. 45—mounted on a shaft that can be adjusted longitudinally by hand. The surface of the rotor and the inside of the casing are provided with hard steel or bronze blades spaced apart by wooden filling pieces. The blades on the rotor are straight. Those on the casting are zigzag.

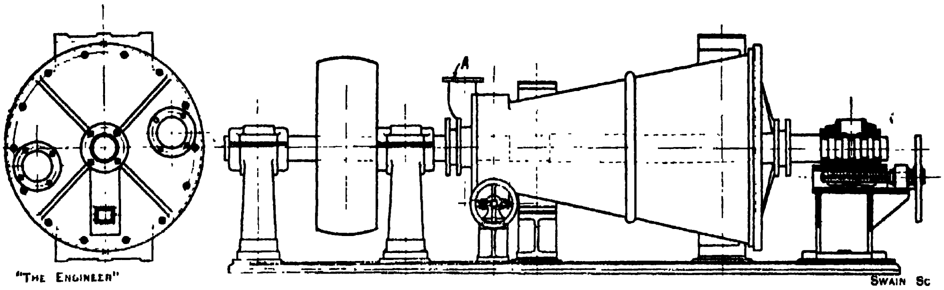


FIG. 43.—Conical Refiner—Masson, Scott.

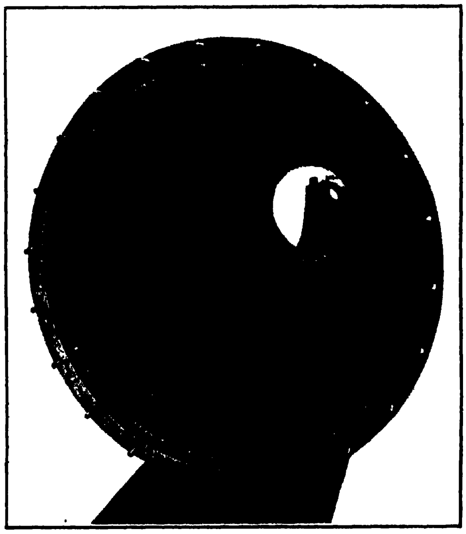


FIG. 44.—Casing of Conical Refiner.

In use the rotor is adjusted by means of its hand wheel and screw until its blades are just rubbing against the stationary blades on the casing. With the rotor running at about 300 revolutions per minute the pulp as delivered from the beating engine is fed into the machine through the hopper A, Fig. 43, situated on the cover of the small end of the casing. The ensuing action is a little difficult to express in an exact and brief manner. It is clear, however, that the pulp as delivered on to the top of the small end of the rotor will be carried round between the rotor blades and at the same time flow towards the larger end of the casing until such time as it reaches that diameter of the rotor at which the centrifugal force exerted on the pulp is sufficient to throw it out into the space between the stationary blades. The heavier particles will obviously be ejected first, so that after the machine has been running for a brief space we can imagine the pulp between the rotor and the casing changing progressively from coarse stuff at the smaller end to fine properly reduced stuff at the larger end. The latter portion may be drawn off through a suitable orifice situated on, and above the centre line of, the large end cover. The coarse particles shot into the stationary blades are deprived of their centrifugal force and fall back on to the rotor. During their fall they are scissored between the blades, so that as their weight is thereby reduced they may travel a little farther towards the large end before they are again shot off the rotor. Thus, while the stuff already sufficiently reduced flows quickly to the outlet, the heavier portions are held back until their size and weight are such as will enable them to pass on.

The upper portions of the rotor and casing are thus primarily concerned in the "refining" action, for if a particle gets into the space between a pair of blades on the lower half of the casing gravity is no longer effective to return it on to the rotor. The lower portion of the casing might, therefore, apparently be made without blades and the action would proceed with little alteration. It is provided with blades for the same reason as the outside of the casing is provided with two sets of pedestal feet—see Fig. 43. In order to equalise the effects of wear the casing is made so that it may be turned over through 180 deg. when occasion requires it.

The machine is made in several sizes, the length of the cone—4 ft. to 6 ft.—being the measurement adopted for distinguishing purposes. The horse-power absorbed necessarily depends upon the tightness with which the rotor is adjusted against the stationary blades. If this adjustment is made carelessly an enormous amount of power may be consumed. We are informed, however, by the makers that when the adjustment was satisfactory and the output of pulp was 1000 lb., as measured in paper, per hour, a 4 ft. refiner of this type showed under test a consumption of 80 horse-power.

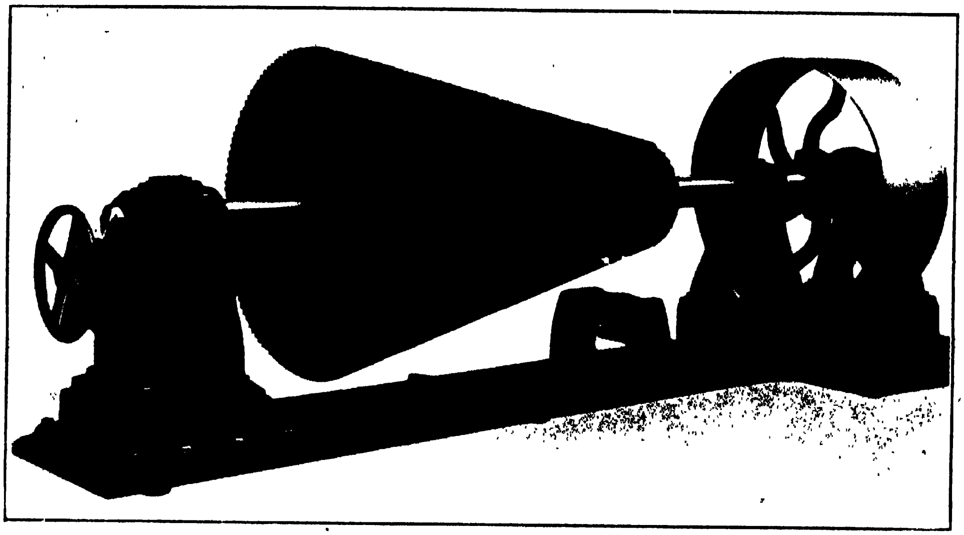
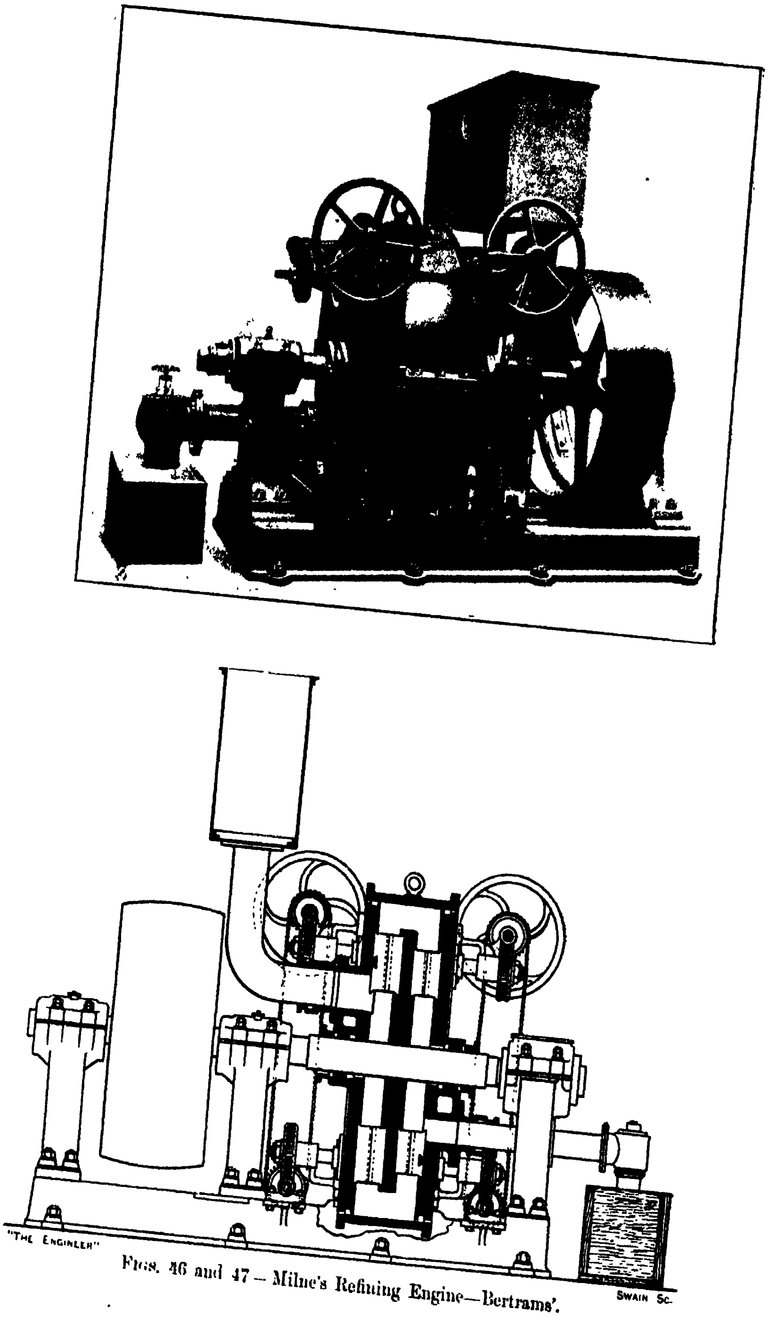


Fig. 45.—Rotor of Conical Refiner.

A refining engine of a materially different type is illustrated in Fig. 46 and in section in Fig. 47. This is Milne's patented refining engine, and is made by Bertrams, Limited, of Edinburgh. The casing of the machine is a short open-ended cylinder closed by two piston-like covers provided with packing rings. A stout shaft passing through glands in the covers carries centrally a disc to each face of which a series of radial bars or knives is fixed. Similar bars are attached to each of the cover discs. The bars on one side of the central disc are shorter than those on the other. A feed box is erected above the casing, and is connected thereto by an elbow pipe, the end of which fits within a gland on the adjacent end cover. On the other end cover a similar gland is provided for an outlet pipe, the two glands being situated at the same radial distance



Figs. 46 and 47 – Milne's Refining Engine—Bertrams'.

from the axis of the shaft, but at opposite sides of it. In connection with each end cover four screws provided with feet work within brackets springing from the fixed cylindrical casing. Each set of four screws is simultaneously adjustable by means of two chain-connected worm shafts.

The bars, the longer of which are not more than 9 in. in length, are made of rolled bronze, and are secured in place by slips of beechwood. The discs and the casing are of cast iron covered with brass or copper. The shaft is made of forged steel sheathed with brass and is provided with enclosed double ball thrust bearings. The feed-box is usually of wood. The inlet and outlet pipes are of copper. The machine is made in two standard sizes, the smaller one being capable of passing 1000 lb. to 1200 lb. of refined pulp per hour, and the other one anything up to 2240 lb. As in the case of the previously described refiner the horse-power absorbed depends entirely upon the manner in which the machine is worked. With the end discs adjusted so that the blades are working in fairly close contact, the horse-power necessary for the larger size of machine is, we are informed by the makers, from 60 to 70.

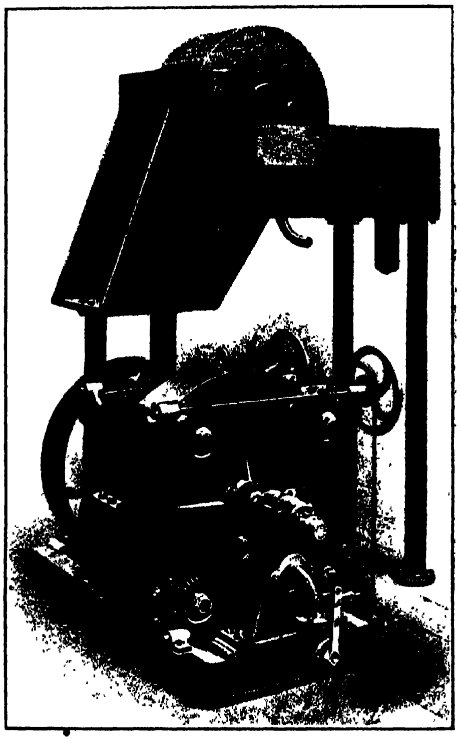


Fig. 48.—Milne Refiner with Concentrator.

In action the pulp from the feed-box is entrained between the larger sets of stationary and moving bars, and is shot outwards by the action of centrifugal force into the annular space beyond the bars. The bars on the other side of the disc are some 2 in. shorter than those through which the pulp has just passed, but their inner ends are at the same radial distance from the axis of rotation. The centrifugal force exerted on a particle at the outer end of the shorter bars is accordingly only about 90 per cent. of what it is for the same particle when at the outer end of the larger series of bars. It follows, therefore, that a liquid delivered on the side of the rotating disc carrying the larger bars would flow over to the other against the centrifugal force imparted to it by the presence of the smaller bars. Whether a particle of matter present in the liquid will accompany it in this flow will depend upon the weight of the particle. If this is above a certain limit the centrifugal force developed in the particle on contact with the smaller blades will shoot it back into the annular space against the flow of the liquid. If the weight is below the limit the centrifugal force thus developed will not be sufficient to counteract the force of the flow and the particle will pass through with the liquid. Gravity acting on the particles introduces a slight complication. Thus it is easier for a particle to pass through the smaller blades above the axis of rotation than below. The situation of the outlet pipe below the axis of rotation no doubt compensates this effect.

In actual use the particles of fibre which fail at first to pass the second set of bars do not simply remain unaffected in the annular chamber, but pass repeatedly between one set of bars and the other until their size has been reduced sufficiently to allow them to escape.

When the ordinary type of hollander beating engine is in use there is, as we have shown, considerable difficulty in circulating the stuff in the vat at that consistency which considerations of efficient beating would otherwise demand. The result in practice is that the pulp must be diluted with water, a proceeding which, although it facilitates the circulation, does not make the beating any easier or more efficient. Efficient refining likewise demands that the pulp should not be diluted beyond a certain degree. With whatever more than a certain amount of water the pulp is diluted, by this amount will the volume of stuff which the refiner has to handle in a given time be increased. To keep the output of fibre—and therefore of paper—the same we must, in consequence, either increase the speed of the refiner, or use a larger size. In the case of the refiner described above the difficulties as regards the circulation of a stiff pulp, present in a hollander beater, are absent, so that it is possible, and in many cases desirable, to deliver the pulp to the refiner in a more highly concentrated state than that in which it left the beater. To meet this requirement a concentrator, such as we described in our fourth article, may be interposed between the two machines. In Fig. 48 we illustrate a special arrangement consisting of a Milne refining engine working in conjunction with a Lister patented concentrator. This concentrator appears to be on the same principle as the washing drum used on a breaking and washing engine. It extracts the water from the pulp to the right extent just before the pulp enters the feed box of the refiner, and returns the water to it after refining has been effected, so that no loss of water, sizing, loading, &c., is incurred.

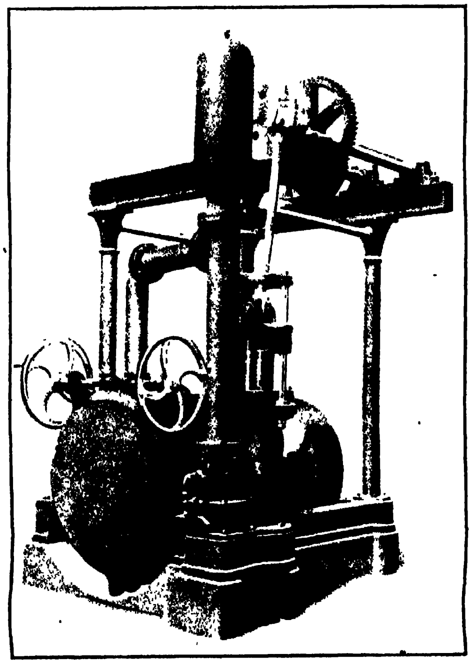


Fig. 49.—Kingsland Refiner.

In Figs. 49 and 50 we illustrate the Kingsland refiner as made by the Glossop Iron Works Company, Limited. In the principle of its action this refiner is very similar to Milne's refiner, but its details differ considerably. As before, the refining takes place in a chamber containing a revolving disc, the action depending on the effect of centrifugal force. The disc is of cast iron, and the bars or knives on each side of it are cast solidly with it. The stationary end covers are similarly of cast iron with solidly cast bars. The adjustment of the contact between the stationary and revolving bars is also effected in a different manner. Thus the back end cover is firmly secured to the cylindrical casing. The knives of the disc are adjusted against the knives of this cover by moving the disc axially, for which purpose a hand screw is provided to bear against the back end of the disc shaft—

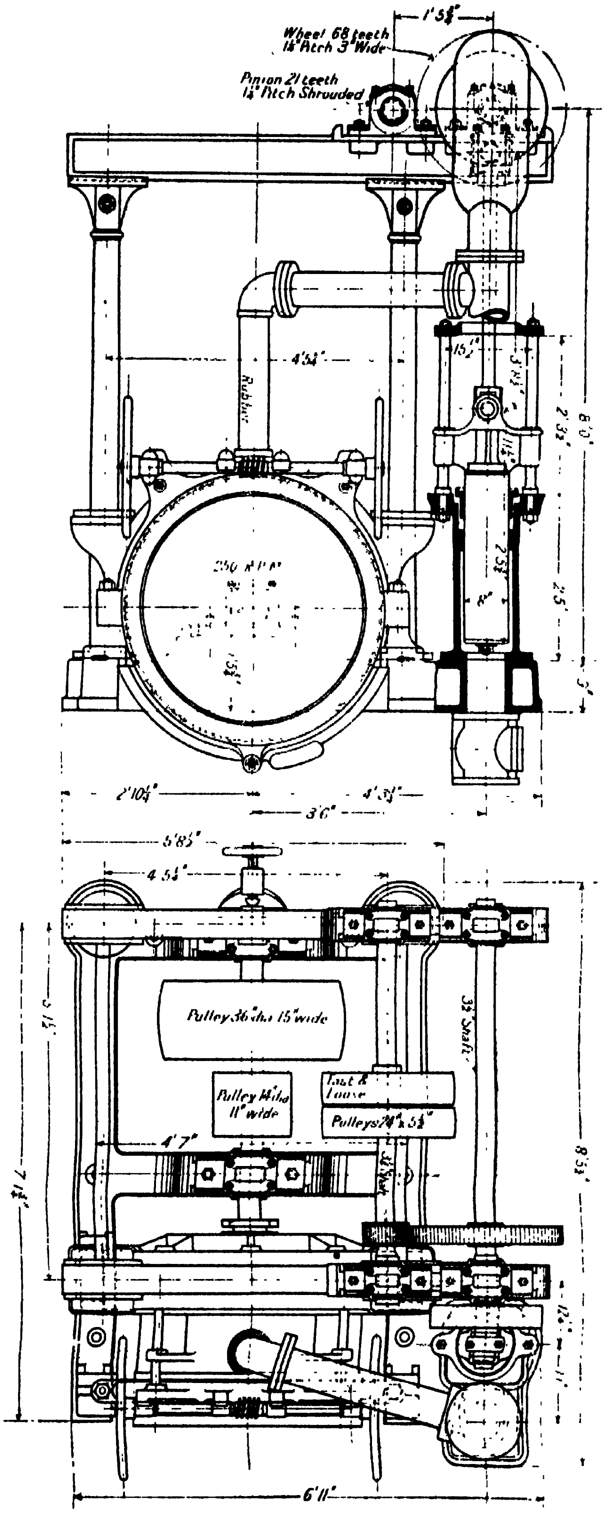


FIG. 50.—Kingsland Refiner—Glossop Ironworks.

see Fig. 50. The front cover can be moved in and out by means of a worm and worm wheel arrangement.

For the size illustrated the diameter of the revolving disc is 48 in. A 39 in. machine is also made. The speed of the disc is 250 revolutions per minute. In the case of the machine illustrated in Fig. 46 the feed of the pulp to the refiner chamber is effected by gravity. The Kingsland refining engine is also made with a gravity feed, the revolving disc in this instance being 30 in. in diameter. The example illustrated, however, has a feed. the pressure of which is controlled, not by gravity, but by a gear driven pump of the plunger type provided with an air chamber to keep the rate of flow constant. The pump ram has a diameter of 8 in. and a stroke which may be either 10 in., 12 in.. or 15 in., according to the amount of pulp to be passed through the refiner in a given time. The variation in the stroke is obtained by altering the position of the pin on the overhead crank disc—see Fig. 49. The pump is driven by belt and gearing from the refiner shaft, and makes forty-five strokes per minute. It delivers the pulp to a point situated at the highest level of the cylindrical refining chamber. The outlet from this chamber is situated as nearly at the centre of the back cover as circumstances will permit. A swivelling pipe, not shown in either of the engravings, can be attached to the outlet orifice, and by adjusting this the back pressure on the pulp passing through the refining chamber can be varied to suit the conditions of the moment.

CHAPTER VII

THE FOURDRINIER MACHINE

In our introductory chapter we stated that there were two broad stages in the manufacture of paper, namely the preparation of the pulp and the conversion of this pulp into dry, continuous sheets of paper. We have now described the construction and working of some typical machines employed in the first stage and have to take up a similar account of the papermaking machine proper, or Fourdrinier as it is sometimes called, after the gentlemen who had so much to do with its successful introduction. Such a machine in its modern form is not a simple piece of machinery; it is, in fact, properly to be described as a collection of machines. In order, then, that its principle of working may not be lost in the description of its details, we will first of all give a brief diagrammatic account of what it is and what it does, without reference to the product of any particular maker.

A papermaking machine may conveniently be divided into two portions—a wet and a dry end. In Fig. 51 we give a diagram showing the elevation of such a machine with every part except the absolute essentials omitted. A plan of the wet end is also given. The plan of the dry end follows obvious lines.

Starting at the left, the pulp as it is delivered from the beating or refining engine, with a suitable amount of diluting water added, is first of all caused to flow through a sand trap. In its sinuous course through this trap, the pulp, flowing over small ridges provided across the channels, deposits any large-sized pieces of sand or dirt it may contain. From here it passes on to a strainer consisting essentially of a plate in which many very narrow slots have been cut, through which only properly pulped fibres can pass. Next comes a sluice whereby the quantity of pulp flowing, and consequently the thickness of the paper to be made, is regulated. The pulp thus prepared is delivered from the sluice through a breast-box on to an endless travelling band of wire cloth, the upper stretch of which is supported on a large number of small rollers. As the stuff is carried forward on this wire cloth, much of its water drains away through the interstices, and the fibres begin to felt together. The liquid rejected—the "back water"—contains a certain amount of fibre, and is caught and used afterwards for diluting a fresh quantity of pulp. The width of the finished paper is settled at this point by means of india-rubber "deckle straps," two endless bands travelling with the wire cloth and regulating the breadth of the stream of pulp.

Near the end the wire cloth passes over two vacuum boxes connected to a suction pump. In passing across these, the sheet of stuff is still further freed from water. At this stage the sheet is in proper condition to receive any required "water mark" or other sign. This is effected by means of a "dandy roll" usually placed between the vacuum boxes. The dandy roll is a light cylinder bearing on its surface the required pattern in raised wire. It presses gently on the wet paper and thins it very slightly beneath the wire pattern. Having passed the vacuum boxes, the paper has to be still further dried before it can with safety be lifted from the wire cloth. For this purpose it is passed between a pair of "couch rolls," the upper one of which is usually covered with felt. The wire cloth passes through these rolls with the paper, and is then turned round the lower roll and led back towards the "breast roll."

The paper, passing forward off the wire, is carried on to a closely adjacent endless band of felt which conducts it through a first pair of "press rolls." These rolls more or less perform the function exercised by the hydraulic, or other press, employed by the hand worker when he has accumulated a "post" or pile composed of alternate sheets of felt and paper. The paper is next passed upward on to a second endless felt, which conducts it through a second pair of press rolls. It may then go through a third pair. When it has been thus sufficiently pressed, it has become practically free from all loose water, and has been consolidated into a comparatively strong sheet. At this point it may be said to have reached the termination of the wet end of the machine.

The paper, although it has now no free water, is still moist, and has to be thoroughly dried. For this purpose it is passed round a series of steam-heated drying cylinders. Our diagram shows a group of thirteen of these cylinders, arranged in two rows and numbered according to the progression of the paper around them. The cylinders are rotated at a uniform rate. The paper not being as yet strong enough to bear its own weight except on very short distances, is held up to the surface of the drying cylinders by means of an endless felt band embracing about half the circumference of each cylinder. A certain degree of tension has to be maintained in the felt band, and as it is difficult to effect this when the band is very long and the variation in its length correspondingly great, it is usual to divide it into several portions. Thus our diagram shows the employment among the thirteen rolls of four endless bands. One embraces the lower halves of the rolls 1, 3, 5 and 7, and another the lower halves of the rolls 9, 11 and 13. A third passes over the upper halves of the rolls 2, 4, 6 and 8, while the fourth deals similarly with the rolls 10 and 12. On leaving the thirteenth roll, the paper now almost dry passes through a pair of smoothing rolls which remove all irregularities from it and generally perform a function similar to that performed in the hand-making processes, when the sheets are pressed without the intervention

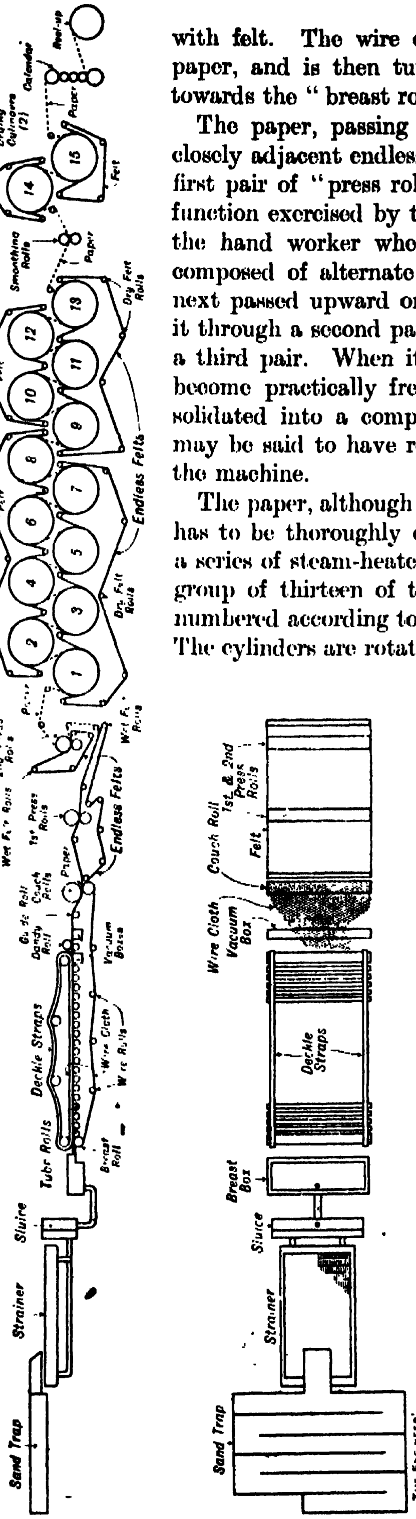


Fig. 51.—Diagram of a Fourdrinier Papermaking Machine.

The Engineer.

of the felt pads. A passage round additional drying cylinders—two are shown in the diagram—then follows, and precedes a passage through the rolls of a calender. The action of this is, as explained in our first chapter, to smooth and polish the surface, to consolidate the fibres and to reduce the thickness and increase the strength of the paper. The last operation is to wind the paper on to a reel.

With this description, the general lay-out of an actual machine will be readily understood. In Fig. 54 the plan and elevation of such a machine is shown, while on pages 58 and 59 will be found two views, taken during erection, one of the wet and one of the dry end. The machine represented in these engravings was constructed by James Bertram and Son, Limited, of Edinburgh, for the Carrongrove Paper Company, Limited, of Denny, and is engaged on the production of the best quality of printing paper, such as is used by certain illustrated journals. The raw material in use is almost entirely esparto-grass with the addition, for some qualities, of a little sulphite wood pulp.

The speed at which a paper machine is run depends upon the weight of paper it is desired to produce. In the present instance the speed is variable between 50 and 250 ft. per minute, representing in a week of 132 hours an output of from 50 to 75 tons. The wire cloth at the wet end has a width of 102 in., which width is suitable for the production of a finished web of paper of anything up to 92 in. wide. The length of the wire cloth is 45 ft. There are seventeen drying cylinders in all, each having a diameter of 4 ft. 6 in. Four calenders having between them a total of twenty-four rolls are provided to enable the required highly finished surface to be obtained.

The driving of the machine is divided into two parts. At the wet end the stuff chests where the pulp is stored have to be provided with agitators to prevent the fibre settling. These agitators, the strainers and the various pumps, &c., are driven by an electric motor from an overhead shaft. The rest of the machine, from the couch rolls right to the reel-up drum beyond the calenders, is driven by rope-gearing from a variable speed steam engine. The total power used is from 50 to 60 horses.

We reserve the description of various details embodied in the design of this and other Fourdrinier machines for a succeeding chapter. The details of the rope drive may, however, appropriately be described here. In the Carrongrove machine this drive as is usual with the makers is on White's patented system. As shown in Fig. 54, the steam engine transmits its power on to a main shaft by means of ropes. From this main shaft the drive is taken also by ropes to ten separate counter-shafts.

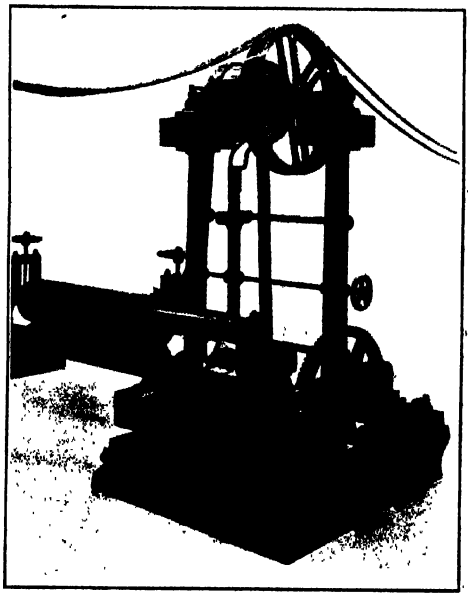


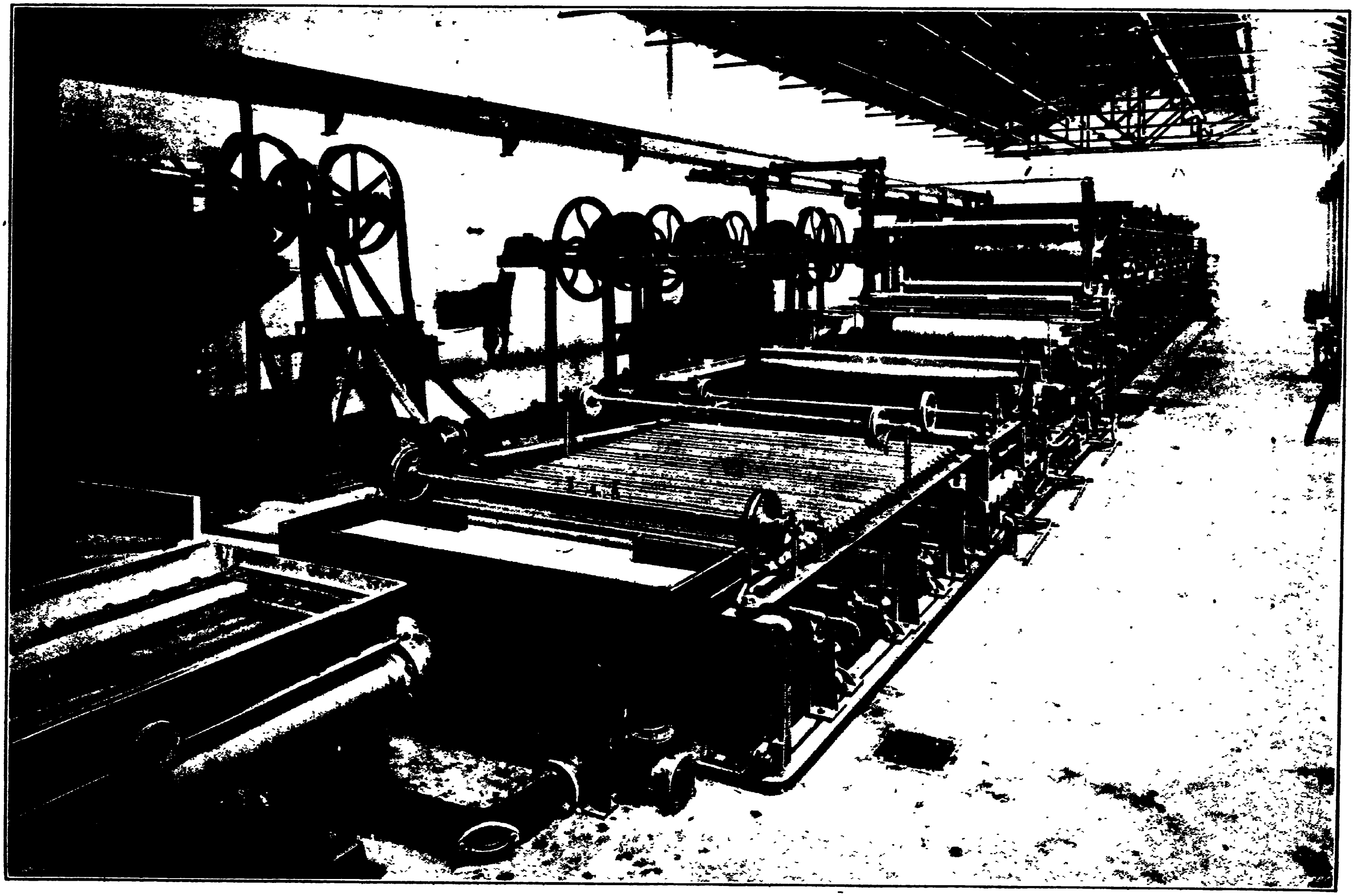
FIG. 52.—White's Driving Gear.

One of these shafts is devoted to the driving of the couch rolls, one to each of the two sets of press rolls, three are associated with the driving of the drying cylinders, and four are given over to the driving of the four calenders. Each of these ten drives is

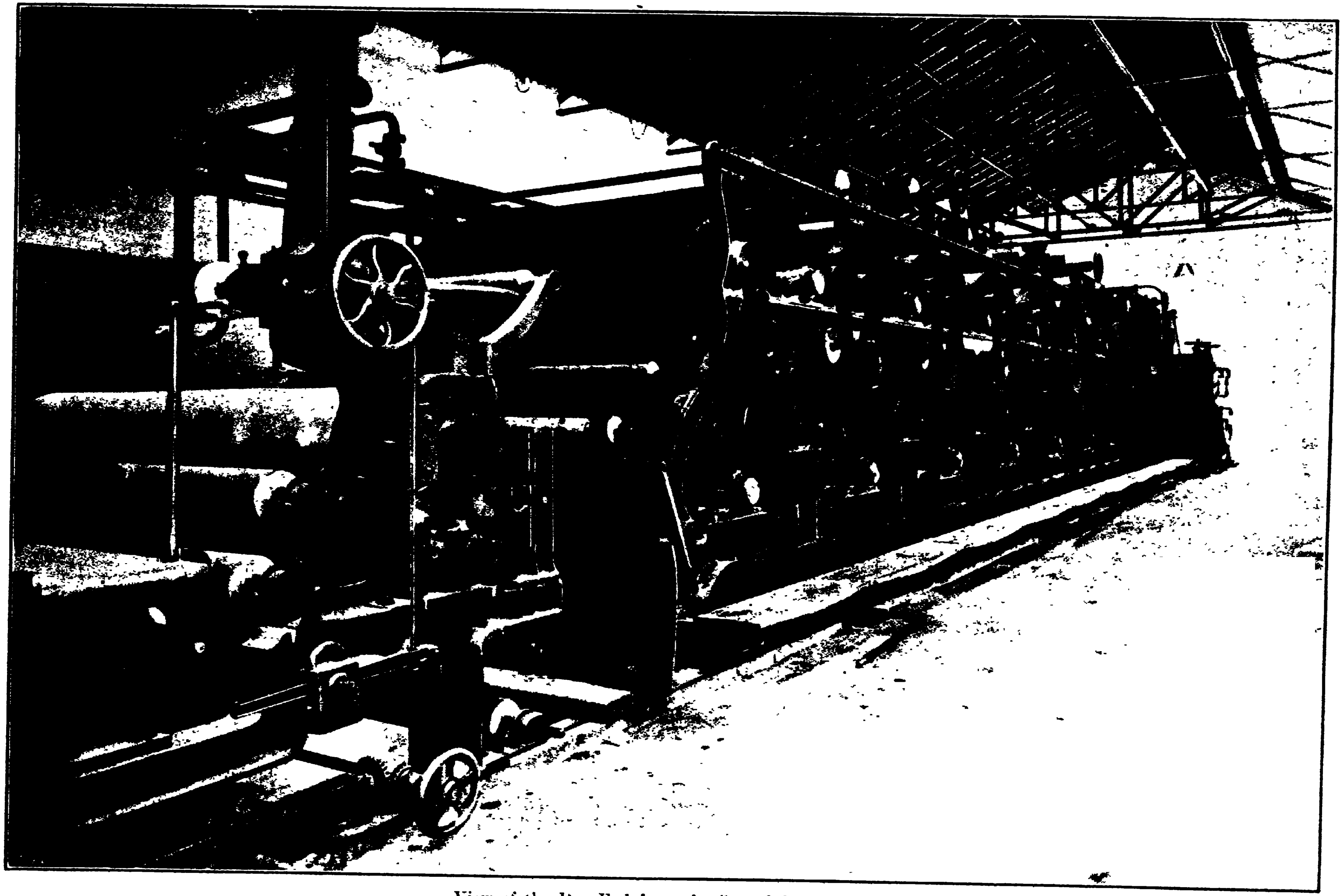
102-INCH PAPERMAKING MACHINE AT CARRONGROVE.

JAMES BERTRAM AND SON, LIMITED, EDINBURGH, ENGINEERS.

(For description see page 57.)



View of the Wet End from the Strainers.



View of the Dry End from the Second Press Rolls.

separately adjustable as regards speed and starting and stopping after the manner shown in Fig. 52. The rope pulley counter-shaft, it will be seen, carries a belt pulley which is slightly coned. From this the power is transmitted by belt downwards to a correspondingly coned pulley on a second counter-shaft, which is in geared connection with the shaft driving the lower of the pair of rolls shown. The second counter-shaft is carried on a frame which can swing in journals embracing the roll shaft. Suitable stops are provided for preventing this frame from falling too far, while a hand lever is connected to the frame in order that it may be raised. Thus, simply by relieving the tension in the belt, the drive can be quickly stopped, while by adjusting the position of the belt on the coned pulleys by means of the screw handle shown the speed of the drive can be varied. The feature of the invention is the suppression of any kind of clutch and the smoothness which it is claimed it gives to the starting and stopping.

Of the seventeen drying cylinders, three, as we have said, are thus directly driven. The remainder are driven from these three by means of gear wheels. The wire cloth at the wet end passes round the lower couch roll, and as this roll is driven by one of the counter-shafts no further provision need be made for driving the wire cloth. The deckle straps partake of the motion of the wire and are not separately driven.

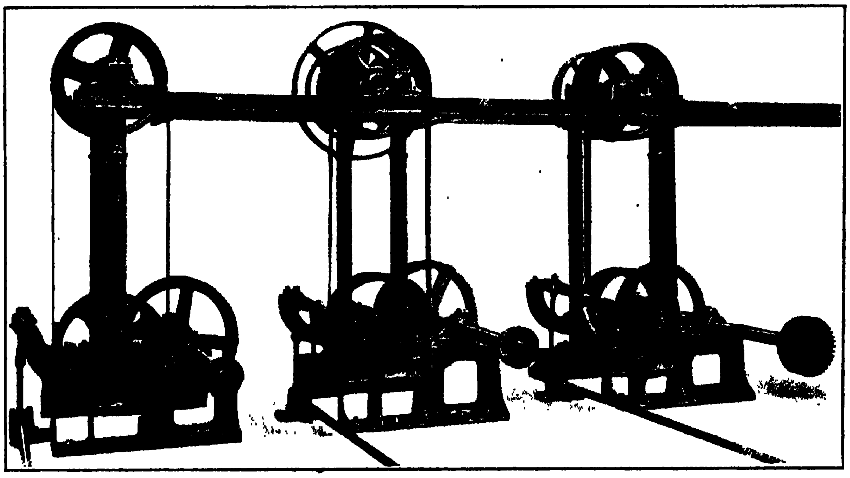


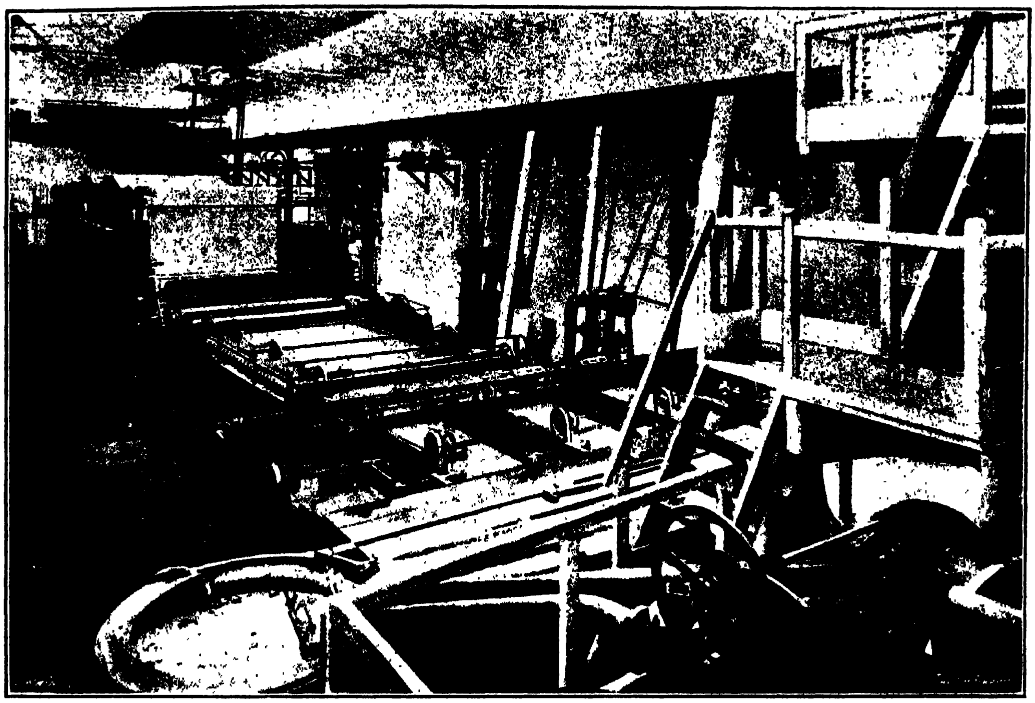
FIG. 53.—Three sets of White's Driving Gear.

In Fig. 53 we show three sets of White's driving gear, being those for the couch rolls and the first and second press rolls respectively from left to right. It will be noticed that in this instance the drive to the counter-shafts is made by belt instead of by ropes. The driving gear of a Fourdrinier, it will be gathered, occupies a considerable amount of floor space along one side of the machine. In a recent instance to be found at Greenhithe, Kent, Messrs. James Bertram have considerably improved matters by placing the bulk of the gear, along with the steam engine, underground. The swinging levers in this case are mounted on the lower or underground shafts, and are operated from above. What would ordinarily be the counter-shafts are situated above-floor and are connected to the rolls and drums just as are the lower shafts in Fig. 53.

The Carrongrove machine dealt with above may be regarded as typical of modern Fourdrinier practice, whatever may be the raw material in use or the exact nature of the paper made. These two variables undoubtedly do introduce modifications

134-INCH PAPERMAKING MACHINE AT THE "DAILY TELEGRAPH" MILLS, DARTFORD.

BERTRAMS, LIMITED, SCIENNES, EDINBURGH, ENGINEERS.



View from Behind the Strainers.

The Wire Cloth and its Frame.

in the design of the papermaking machine, but in general it may be said that these modifications are apparent only in the details of the machine and in the speed at which it is run. In particular, a Fourdrinier intended for "news" papermaking, for which the raw material is, of course, wood pulp, need be very little different from any other except as regards the speed at which it is run. As examples of "news" making Fourdriniers we cannot do better than refer to the machines employed at the *Daily Telegraph* mills at Dartford. Of the five machines there employed, two were supplied by Bertrams, Limited, of Edinburgh, and it is to these two that our succeeding remarks apply. Eight views of the larger of these two machines will be found in the previous and succeeding pages.

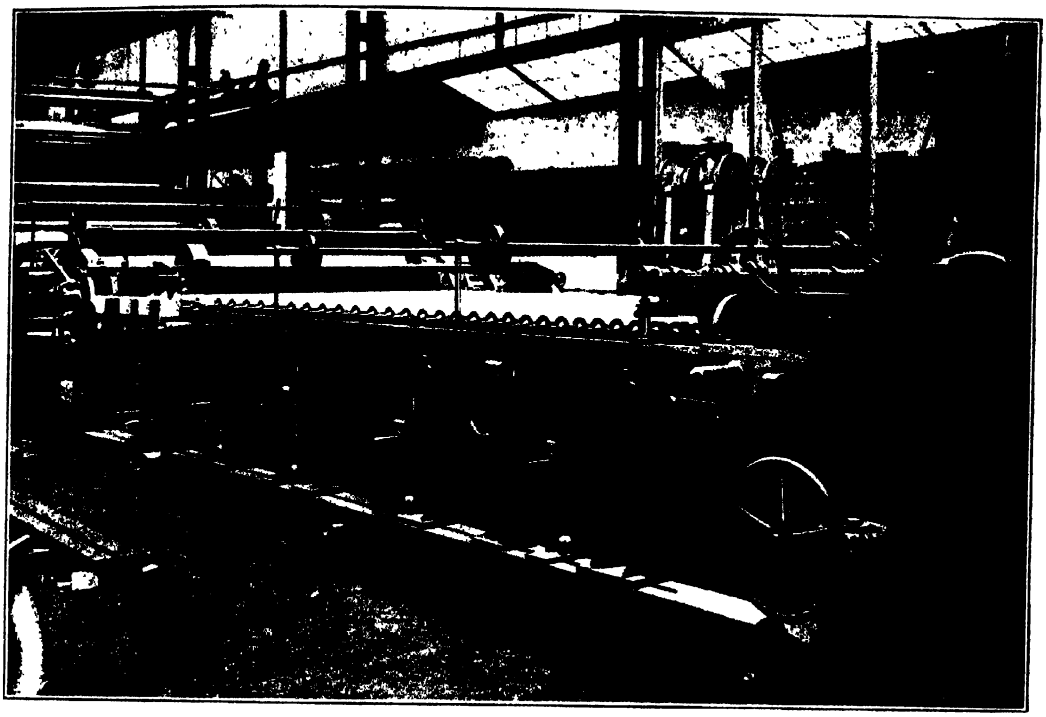
The first view gives a general idea of the machine as seen from a point in rear of the strainers. Towards the right may be seen one of the circular stuff chests into which the pulp flows by gravity from the beaters. Lying over the pair of stuff chests, and surrounded by a wooden platform, is the "top chest," a large vessel into which the pulp is raised from the stuff chests by the stuff pumps. There is an overflow from the top chest back into the stuff chests, so that a constant head of pulp may readily be maintained at all times in the top chest. Leading out of the top chest there is a pipe which conducts the pulp by gravity to the "mixing box," a cylindrical vessel with a conical bottom, the top of which is visible in the foreground. If desired, the pulp can thus be passed directly into the mixing box. Usually, however, between the top chest and the mixing box it is sent through a refining engine situated on an alternative pipe between the chest and the box. The refiner in this case is of the Milne type, and is to be seen in the foreground. In the mixing box the pulp is diluted to the proper extent with the "back water" which drains away from the wire cloth and which enters the box through a pipe at the foot. From the mixing box the diluted pulp flows over the sand tables which may be seen, in the engraving, passing across the room. From the sand tables the pulp flows into the five strainers and thence through the breast box on to the wire cloth. The couch rolls and press rolls are barely distinguishable in this view, but a conspicuous feature in the middle distance is the vertical portion of the felt band, where it rises over the stretching rollers. Beyond this is the dry end with its twenty drying cylinders.

The second engraving is a close-up view of the wire frame. On the extreme right we see the end of the breast roll spindle, and on the extreme left the end of the first vacuum box. The corrugated iron sheets arranged beneath the wire rollers to catch the water, &c., draining away from the pulp should be noticed. A view of the wire frame, as partially erected in the makers' shops, is given in the third engraving. The wooden erection on the right is the sluice and breast box.

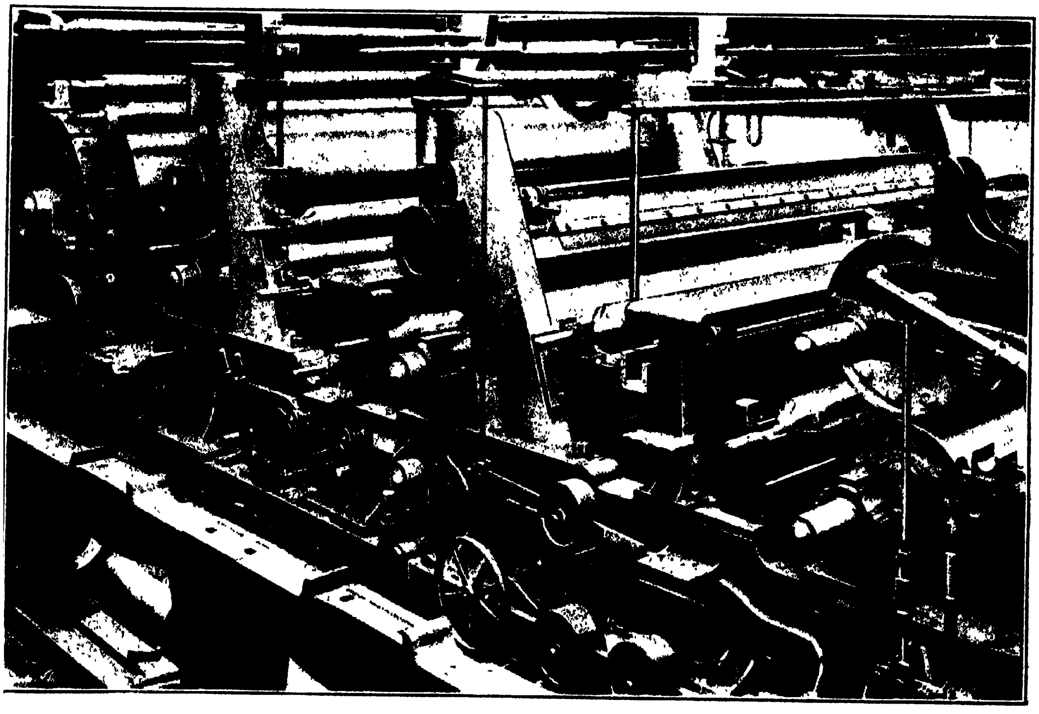
The fourth view, also taken in the makers' works, shows on the right the pair of couch rolls followed towards the left by two pairs of press rolls. The upper of the first set of press rolls is not in place, but a scraper to remove any fibre that may adhere to it is seen being fitted in place. The various small rollers seen in this view are for the guidance of the different endless felt bands. In the background the first pair of drying cylinders is seen.

The fifth engraving shows a portion of the two rows of drying cylinders. The odd and smaller-sized cylinder on top does not help to dry the paper. It is steam-heated like the rest, but is intended solely for drying the felt. There is at least one such felt-drying cylinder for each endless band. The felt passes round it on its return side. The sixth engraving shows the complete set of drying cylinders. The seventh shows the same side of the machine, looking, however, towards the wet end. In the immediate foreground is the calender, with the rolls on which the dried and calendered

134-INCH PAPERMAKING MACHINE AT THE "DAILY TELEGRAPH" MILLS (*continued*).



Wire Frame in the Makers' Works.



Couch and Press Rolls in the Works.

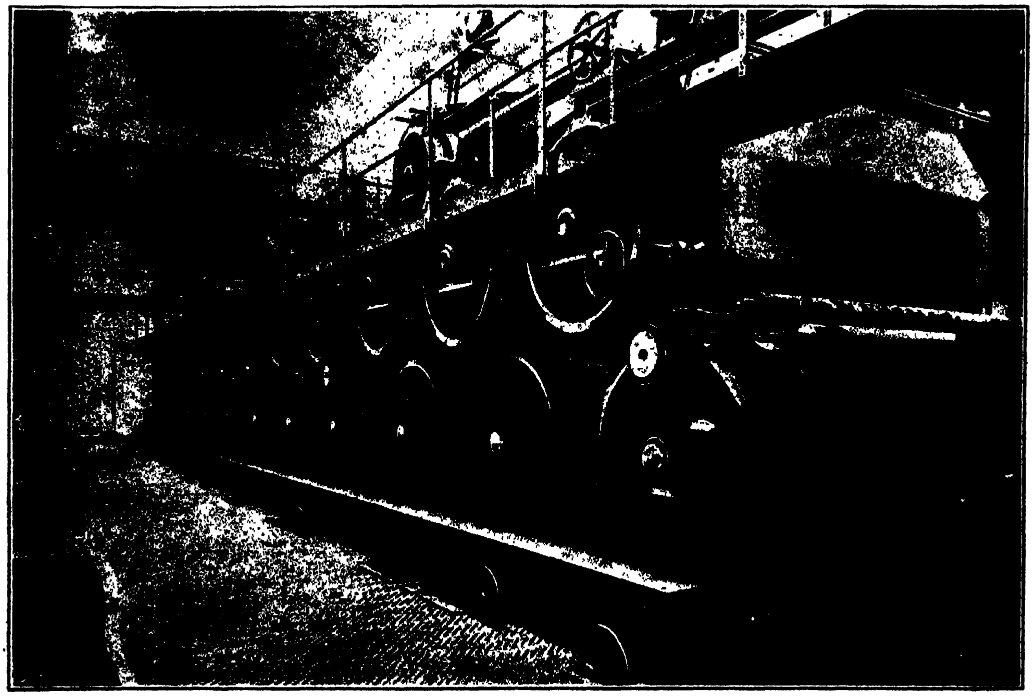
paper is reeled still nearer the camera. The eighth view is also taken from the calender end, but represents the opposite side of the machine. There all the driving gear is accommodated. In Fig. 55 a general arrangement drawing of the whole machine is given. Since the machine was built, a third set of press rolls has been added to it.

The machine thus illustrated has a wire cloth 134 in. wide. The other machine made by Messrs. Bertrams for the same mill has a wire 94 in. wide. The two machines are to all intents of the same general design, and are employed for making the same class of paper. It is interesting to compare the following figures relating to them.

Machine, No.	3	5
Wire—Width	94 in.	134 in.
Length	60 ft.	60 ft.
Speed	400 ft. per min.	500 ft. per min.
Strainers—No.	4	5
Size	6 ft. × 2 ft.	6 ft. × 3 ft.
Auxiliary strainer, size	6 ft. × 2 ft.	6 ft. × 2 ft. 6 in.
Breast roll, diameter	13 in.	15 in.
Guide roll, diameter	8 in.	10 in.
Wire rolls No.	5	5
Diameter	7 in.	8 in.
Tube rolls—No.	42	34
Diameter	4 in.	33 at 5 in., 1 at 6 in.
Vacuum boxes, No.	3	3
Deckle pulleys, diameter	15 in. and 9 in.	15 in. and 9 in.
Couch rolls, diameter	16 in. and 24 in.	20 in. and 24 in.
Press rolls, No. of sets	2	3
First set—Top roll	18 in., basalt lava	22 in., chilled iron
Under roll	16 in., brass	20 in., brass
Second set—Top roll	18 in., chilled iron	22 in., chilled iron
Under roll	16 in., brass	20 in., brass
Third set—Top roll	--	22 in., chilled iron
Under roll	—	20 in., rubber
Drying cylinders No.	24	20
Diameter	48 in.	61 in.
Length	92 in.	132 in.
Felt driers—No.	4	4
Diameter	3 ft.	3 ft.
Wet felt rolls, diameter	6 in.	8 in.
Wet end leading rolls—No.	4	4
Diameter	6 in.	7 in.
Dry felt rolls, diameter	6 in.	7 in.
Calender—No. of chilled rolls	5	7
Diameter, inches	18, 13, 15, 13, 15	20, 15, 14, 15, 14, 15,18
Pumps—Stuff pumps	1 at 9 in. bore × 16-in. stroke	2 at 9 in. × 16 in.
Back water pump	7-in. bore	9-in. bore
Excess water pump	4-in. bore	4-in. bore
Vacuum pump, No. of barrels	2	4
Size	10 in. × 16 in.	10 in. × 16 in.
Main engines—No.	2	2
Type	Horizontal cross coupled	Compound vertical
Cylinders	12 in. × 18 in.	14 in. and 20 in. × 8 in.
Steam pressure	90 lb.	—
Horse-power, total	50–100	—
Auxiliary engine—		
Type	Horizontal single	Compound vertical
Cylinders	12 in. × 24 in.	14 in. and 20 in. × 8 in.
Horse-power	35	—
Horse-power taken by body of machine	70	—
Ditto by auxiliaries	30	—
Total	100	100
Output of paper per week	75–80 tons	130 tons

134-INCH PAPERMAKING MACHINE AT THE "DAILY TELEGRAPH" MILLS (*continued*).

Some of the Drying Cylinders.



The Dry End.

In connection with these data, several remarks, explanatory and otherwise, fall to be made. Thus a word of explanation may be desirable as regards the function of the auxiliary strainer. This strainer deals with the stuff rejected by the main strainers and is intended to recover the usable material which is unavoidably held back with the impurities. The main strainers have to strain the pulp just at the same rate as the paper is being made. The auxiliary strainer does not need to work to a time limit and can, therefore, do the work with greater care. The stuff saved by it is mixed with the "back water." The ordinary positions of the breast, guide, wire and tube rolls are indicated on Fig. 51. The first three kinds in both the *Daily Telegraph* machines are of copper, the last being in the form of brass tubes. The function of the guide roll is to help maintain the wire cloth in a central position, that is to say, to prevent it from running to one side or the other of the tube rolls. The manner in which it exercises this function will be dealt with in a succeeding chapter devoted to the details of the Fourdrinier. The functions of the three other classes ot rolls are obvious.

The wet felt rolls as indicated in Fig. 51 serve to guide the endless felt bands associated with the press rolls. They are of copper. The wet end leading rolls are also of copper. They are the small rolls over which the paper passes by itself between the last press rolls and the drying cylinders. In both the *Daily Telegraph* machines there are four of these leading rolls. They are driven by power, their function being to assist the movement of the paper. We will refer to Messrs. Bertrams' patented leading roll in a later chapter.

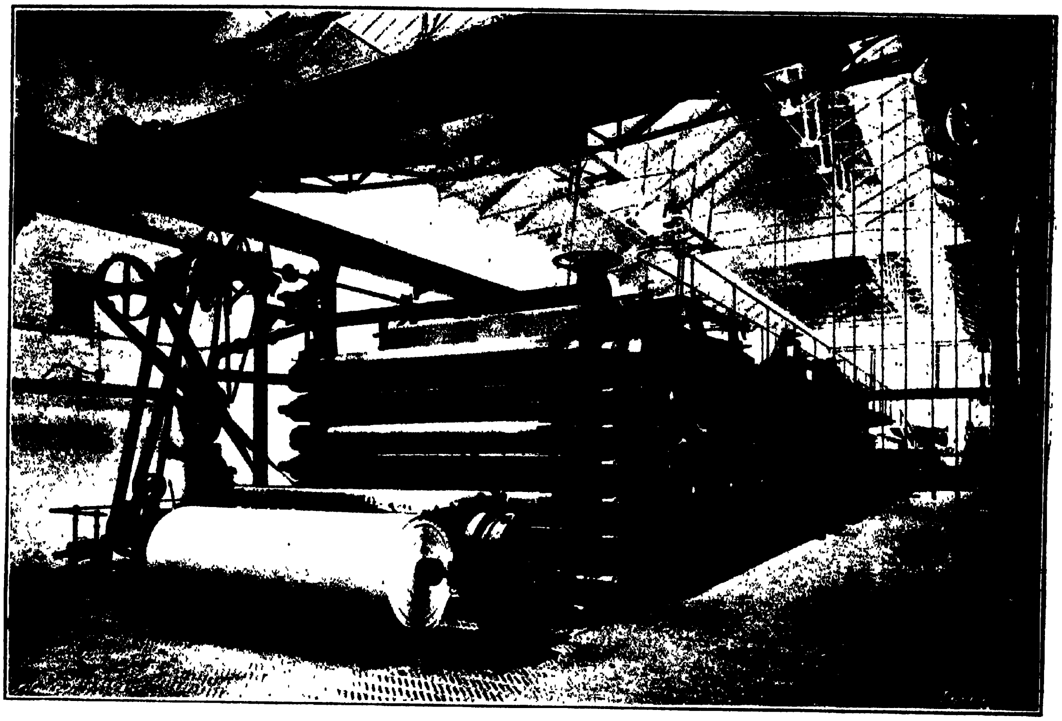
The dry felt rolls serve to guide and support the felt bands associated with the drying cylinders—see Fig. 51. They are, in the *Daily Telegraph* machines, of steel covered with copper. A power-driven leading roll 8 in. or 10 in. in diameter may be associated with each dry felt.

Of the four kinds of pumps referred to, the first—the stuff pumps—deal with the pulp on its passage from the beater house to the storage tanks in the machine house. The back water pump is of the centrifugal type and handles the water which drains away from below the wire cloth. This water contains a fair proportion of fibre, and is therefore valuable. A portion of it is used for diluting the pulp as it leaves the refiner, while the excess is sent through a Füllner filter—a German machine—which recovers the bulk of the fibre. There are other sources of water at the wet end. Thus a flow of water, as we shall see later, is required to seal the vacuum boxes. Water is used to wash the felts and the couch rolls and so on. All this excess water is kept apart from the valuable back water and is dealt with by a separate centrifugal pump. The vacuum pumps are of course required in connection with the vacuum boxes.

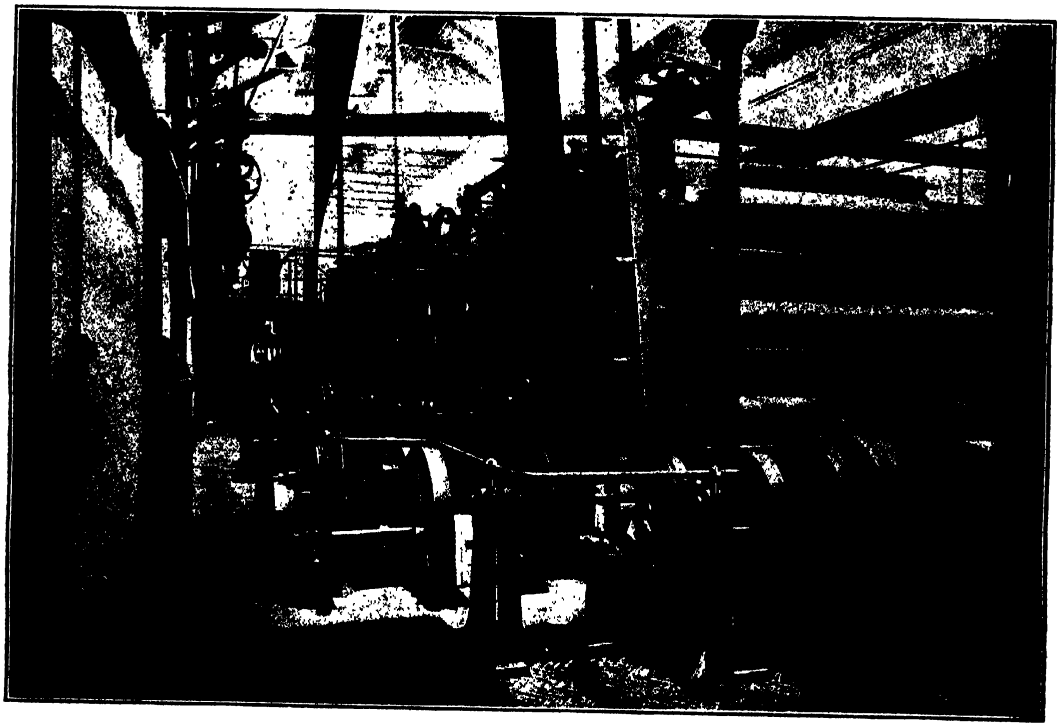
The main engines drive the Fourdrinier proper from the breast roll to the reel-up beyond the calender. The auxiliary engines drive the back-shafting from which the pumps, strainers, agitators in the storage vats, &c., are operated.

The output figures relate to a week of 132 hours. Paper machines usually run continuously from Monday morning till Saturday midday. With regard to the horse-power items, the figures given above are those supplied to us by the makers of the machines. When we had the pleasure of visiting the mill, the engineer in charge informed us that the main engines of the larger machine indicated 90 horse-power, while the auxiliary engine indicated 120 horses. The back-shafting of the larger machine, however, has to drive a Milne refiner which may absorb up to 80 horse-power. The comparable figures are thus 90 for the main engines and 40 for the auxiliaries, as against 50–100 and 35 respectively for the smaller machine. It will thus be seen that the horse-power provided for the two machines and their auxiliaries is practically the same, although one has an output 60 per cent. greater than the other.

134-INCH PAPERMAKING MACHINE AT THE "DAILY TELEGRAPH" MILLS (*continued*).



Reel-up, Calender, and Drying Cylinders.



Driving Side of Dry End.

This result is in part explained by the fact that the back-shafting and drying cylinders of the larger machine are fitted with roller bearings. It should also be noticed that the output of a Fourdrinier is proportional to the effective width of the wire and to the speed of its travel. The increased speed of the larger machine calls for more power to an extent which is probably just about balanced by the saving due to the roller bearings. The increased width demands little if any increase of power, and, if any, principally in the auxiliary engine.

CHAPTER VIII

FOURDRINIER DRIVING ARRANGEMENTS

In the immediately preceding chapter we dealt with one form of drive for Fourdrinier machines. The subject is of prime importance, for on the possibility of having a steady, trustworthy and easily controlled drive the whole success of the Fourdrinier depends. There are many forms of driving arrangements in existence ar [illegible] existence. In this chapter we propose to deal with a few of the former class, which may fairly be regarded as typical. Our examples cover the three branches of the field, namely rope, belt and electrical driving.

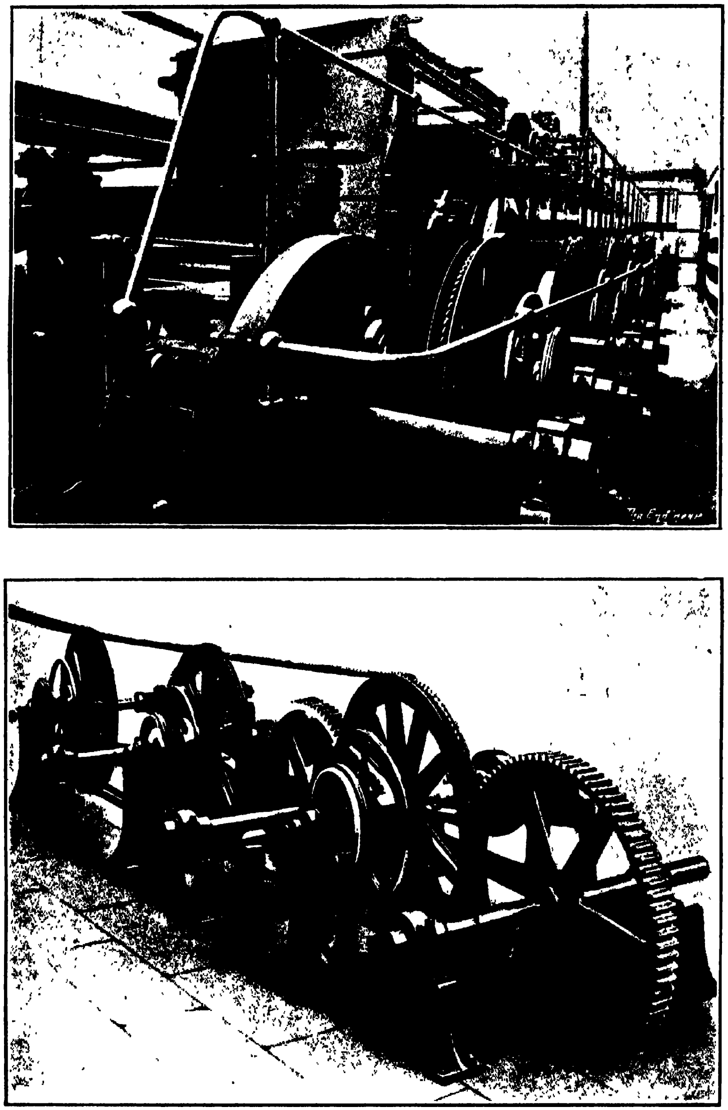
Some curiosity may be expressed as to why it is desirable to split the drive of a Fourdrinier into so many separately controllable parts. We may be tempted to ask why are not all the rolls and drums connected up to the source of power by a geared or other rigid form of drive which would be arranged to give at all times a uniform peripheral speed throughout all parts of the machine. As a matter of fact, this would not fulfil the object in view, namely, the avoidance of breaks in the web of paper, but defeat it. Uniformity of peripheral speed is not desirable, because as the paper progresses through the machine it becomes drier and drier, and accordingly shrinks. In proportion as it shrinks, so must the peripheral speed of the parts supporting it be reduced if breakage is to be avoided.

The shrinkage of paper varies greatly with the raw material in use. Further, with any one raw material it varies with the humidity of the atmosphere, and still more with the differences in the treatment employed in the preparation of the pulp. As illustrating the latter point, we may quote some figures obtained by Mr. W. R. Sindall as a result of experiments carried out a few years ago. It was found that cotton rags beaten for four hours produced a sheet of dry paper 1·1 per cent. less in area than that theoretically equivalent to the width between the deckle straps and the speed of the wire cloth. For eight hours' beating the shrinkage was 4·6 per cent., and so on, progressively, up to a shrinkage of 21·2 per cent. for a beating period of thirty-seven hours. These are shrinkages of area. The linear shrinkages will be almost exactly one-half of these figures. All things considered, then, we may say that the calender end of a Fourdrinier may at times have to run slower than the couch rolls by an amount of the order of 10 per cent.

It is quite common to find, as in the case illustrated in our preceding chapter, the drying cylinders driven in three or more groups. It is not, however, by any means unusual to find them all driven as a single group from the one counter-shaft. The gradual reduction of the peripheral speed of the cylinders towards the dry end, so as to allow for shrinkage, is then accomplished by reducing the diameter of the cylinders progressively from one end to the other. Obviously, this method is best suited to the case of a mill constantly engaged on but one class of paper. It would scarcely answer on a machine running one week on wood pulp, say, and the next on rag.

The form of drive already dealt with cannot be described either as a pure belt or a pure rope drive. In it, as we have seen, either ropes or belts are used to transmit the power from the main countershafts, with belt drives from the sectional countershafts to the spindles to be driven.

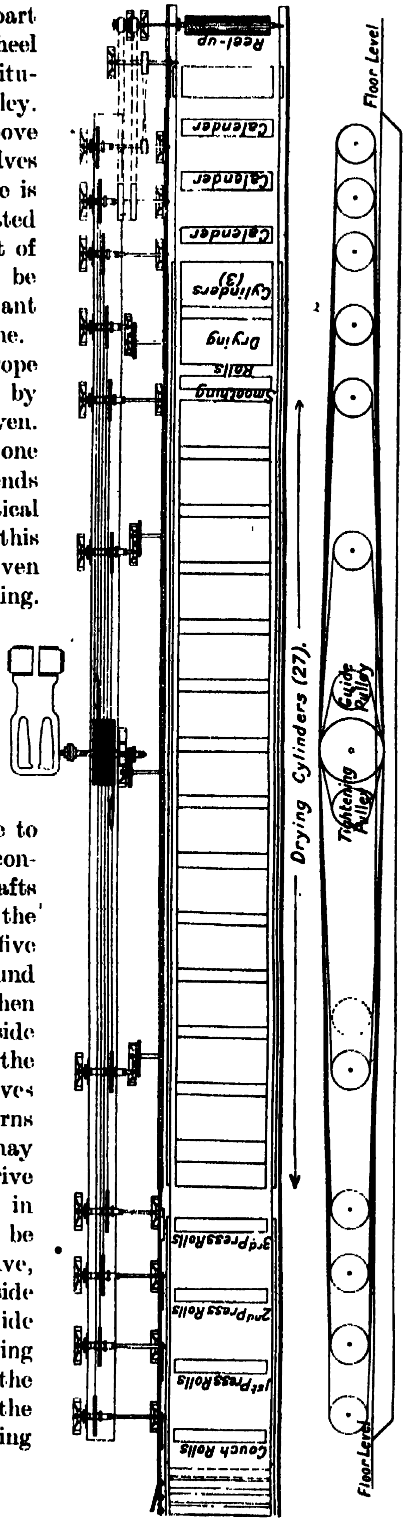
At the *Daily Telegraph* mills, the two machines supplied by Bertrams, Limited, are fitted with what we may call a pure rope drive. The engraving, Fig. 56, shows the driving side of the smaller, that is, the 94 in. machine. Fig. 57 represents three sets of the same style of gearing as arranged for driving the three calenders of a similar machine. Each sectional countershaft, it will be gathered, carries a friction clutch, a hand wheel, an expanding rope pulley, and a cut steel pinion. This pinion meshes with a wheel fixed on the couch or press roll spindle or other shaft to be driven. The



Figs. 56 and 57.—Expanding Rope Pulley Driving Gear—Bertrams'.

rope pulley is in halves, the distance apart of which is controlled by the hand wheel through the agency of scissor-like arms situated between the real arms of the pulley. The adjustment in the size of the rope groove produced by the axial movement of the halves can be effected even though the machine is running. The friction clutch is operated through a shaft from a lever at the front of the machine, so that any section may be started or stopped without the attendant having to pass to the back of the machine.

In Fig. 58 the general lay-out of the rope drive fitted to a large machine supplied by Bertrams, Limited, to an English mill is given. As usual, the main engine—a horizontal one in this case, although modern practice tends towards the adoption of high-speed vertical engines—drives a main shaft. From this shaft power is transmitted by rope to eleven countershafts, and to a twelfth by gearing. The couch rolls, each of the three sets of press rolls, the smoothing rolls, and each of the three calenders, have separate countershafts. The thirty drying cylinders are driven at four points. There are eleven drying cylinders to the first of these four shafts, eight to the second, eight to the third, and three to the fourth. The driving rope is in one continuous length. There are five countershafts on one side of the main shaft and six on the other. The rope is led round each of the five pulleys in succession, with a half turn round the main drum between each pair. It then passes round the six pulleys on the other side in a similar manner, the half turn round the main drum for this side falling in grooves alternating with those filled by the half turns of the other side. In order that the rope may be continuous, and in order that the drive on both sides of the main shaft may be in the same direction, it is necessary, as can be easily verified by trying a sketch of the drive, to provide an idle guide pulleys on each side of the main drum shaft. One of these guide pulleys is arranged to act as a tightening pulley which will take up the slack when the rope length alters from a change in the humidity of the atmosphere. This tightening



"The Engineer"

Swain Sc.

Fig. 58.—Bertrams' Expanding Pulley Rope Drive applied to a Large Machine.

pulley also comes into action, of course, when the speed of any section is varied. As shown in Fig. 59—wherein is given a view of a semi-electrically driven machine—the tightening pulley runs on a carriage on which a weight A constantly pulls.

Among several important features claimed by Messrs. Bertrams for this form of drive, we notice the fact that no overhead shafts are required for it. All the countershafts and the main shaft are carried in pedestals from the floor, and need not be more than 30 in. above it. The small cubical space occupied by the whole arrangement is also emphasised. Like all good drives, it runs, the makers claim, without producing the least tremor in the paper.

As an example of a pure belt drive we may refer to the Lumsden patented system, the invention of Mr. Thomas Lumsden, the late director of James Milne and Son, Edinburgh. A plan of this drive is shown in Fig. 60. The steam engine, it will be seen, drives a main countershaft from which power is taken through herring-bone gearing and a friction clutch for the purpose of driving the drying drums. These, as shown, may be driven in one group by inflexible gearing, and the required variation of peripheral speed obtained by progressively reduced diameters. The main countershaft drives by belt on to two subsidiary countershafts, of which that for the wet end is shown in the engraving. Each subsidiary shaft carries as many coned belt pulleys as may be required, say three, as for the couch rolls and first and second press rolls. The transmission is made from these pulleys by belt to correspondingly coned pulleys on separate shafts, from which, through friction clutches and gearing, power is transmitted to the respective set of rolls.

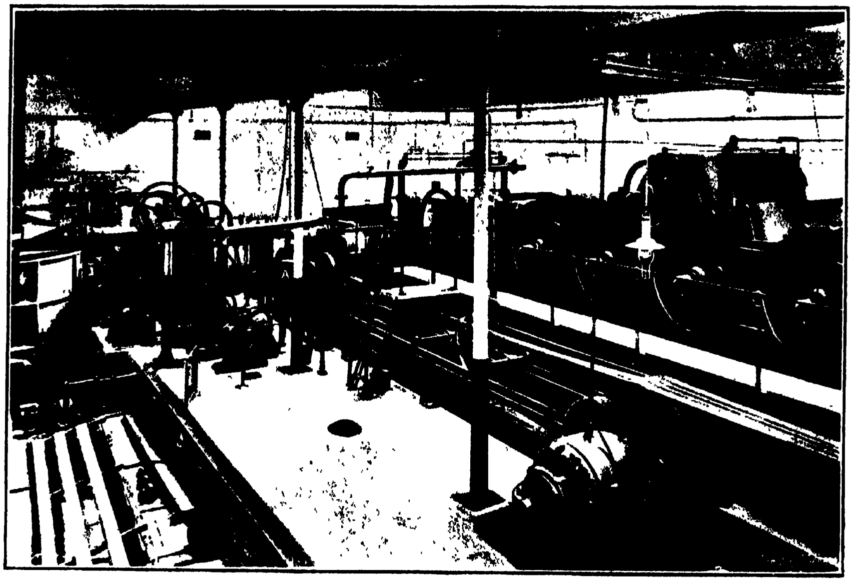


FIG. 59. Rope and Electric Drive—Bertrams'.

The feature of interest in the drive resides in the slight displacement of each driven coned pulley relatively to the corresponding driving coned pulley. This simple stratagem is illustrated in an exaggerated manner in Fig. 61. The amount of displacement depends upon the distance between the pulleys and the angle of the coned surfaces. By comparing the two diagrams in Fig. 61, it will be seen that the displacement gives the belt a flat contact over each half pulley surface without material local stretching of the belt leather. Each belt is guided at one end only. At the free end it finds its own position on the coned surface. Complicated belt shifters, with the attendant production of chafed edges, are thus avoided. The angle of the cones is such that a speed variation of from 5 to 10 per cent. is available at each point driven. A second important feature of this drive is the use of narrow high-speed belts instead of the usual broad and slow-speed type. The belt speeds are on the average 10 ft. per foot of paper run, always provided this does not give a belt speed greater than 4800 ft. per minute.

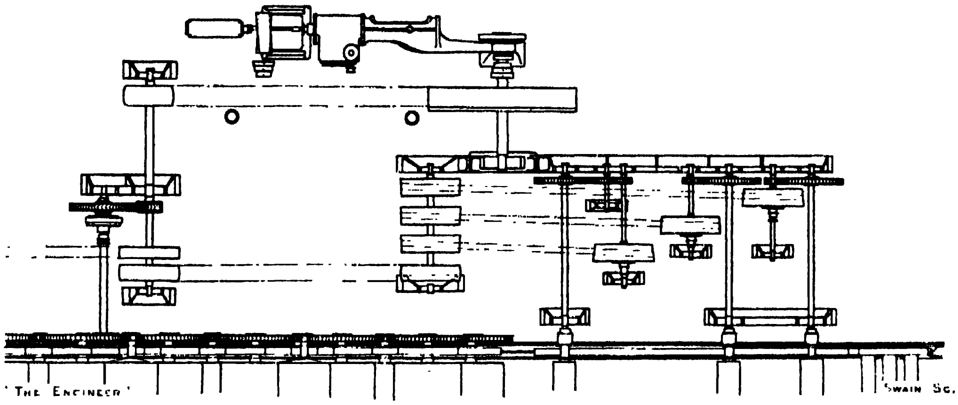


FIG. 60.—Lumsden Belt Drive—James Milne.

The presence of a friction clutch in the driving arrangements of a Fourdrinier is sometimes objected to by paper makers. It may be doubted if the objection is always well founded. Of the drives already described, one avoids the use of friction clutches and two—neither of which can be said in any way to be unpopular—use them. In the case of the expanding rope pulley gearing fitted by Bertrams, Limited, the clutches used are of the Moore and White type, and after years of experience Messrs. Bertrams inform us that these clutches "work admirably."

Nevertheless, the prejudice against the use of friction clutches does exist in some quarters, and to meet the consequent demand for something else, a form of belt drive containing no friction clutches is supplied by Bertrams, Limited. The details of this drive, as applied to a roll, are shown in Fig. 62. From an overhead shaft provided with a coned pulley a belt passes round a correspondingly coned pulley supported from the floor, with its axis at right angles to the axis of the roll. A loose pulley is provided close up against the smaller diameter end of this coned pulley. From the pulley shaft the transmission is made through bevel wheels running in an oil-tight casing. The belt-shifter is operated through a shaft from a hand lever at the front side of the machine. A sector plate is provided for the hand lever, and within the open arc of this there is a stop, the position of which may be adjusted by a screw and wheel. By making use of this stop, the attendant, after having stopped the section,

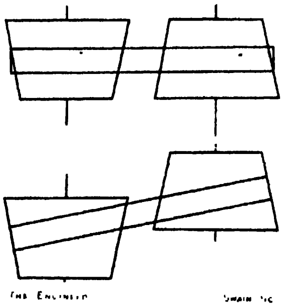
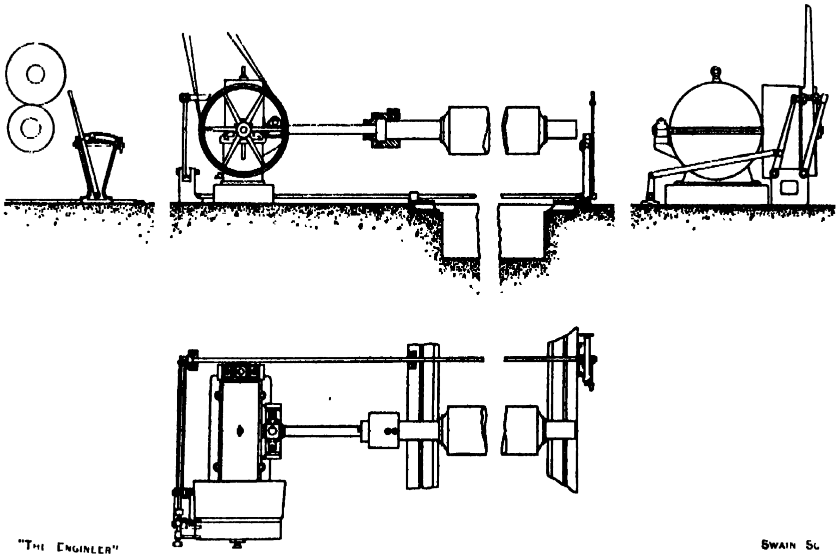


FIG. 61.—Lumsden Drive—Diagram.

can re-start it and bring the belt back on to exactly the same position on the coned pulley as before. If the speed was right previously, there is thus neither trouble nor waste of time in arriving at it again.

In an actual machine fitted with this form of drive we find the overhead shafting extends along the wall from a point abreast the couch rolls to a point abreast the last calender. As usual, the pair of couch rolls, each of the three sets of press rolls, and each of the four calenders, is driven by a separate pair of coned pulleys. The reel-up spindle is driven by belt from the last calender. Of the eighteen drying cylinders, the first seven are driven in one, followed by a separately driven group of eight, with another group of three beyond the smoothing rolls. The smoothing rolls are not in this case driven separately, but take their power by belt from the shaft driving the last of the cylinders.


"THE ENGINEER"

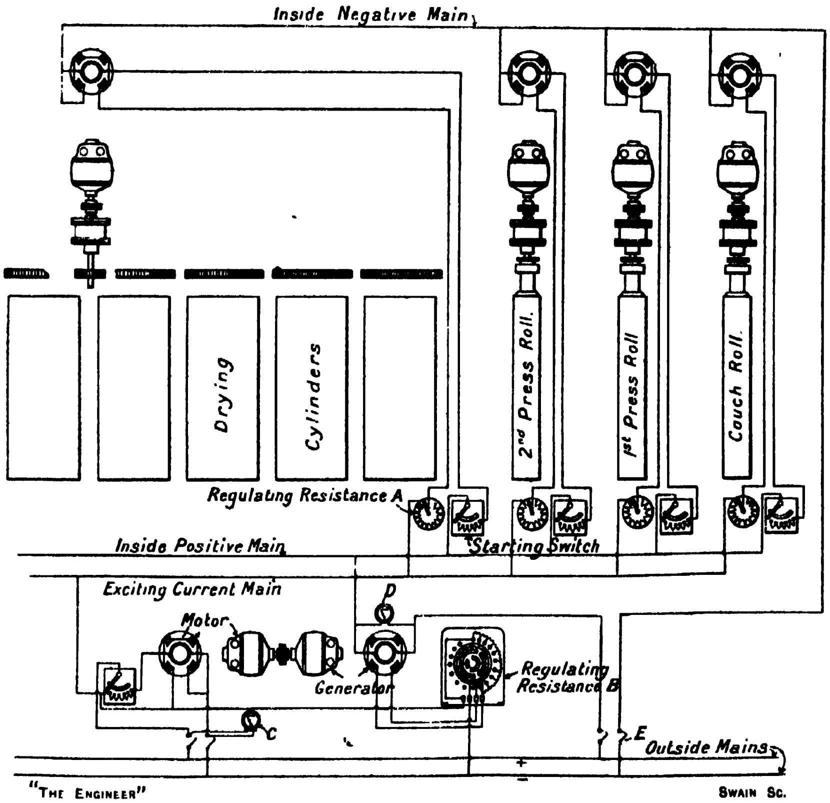
SWAIN SC

FIG. 62. Belt Drive without Clutches—Bertrams'.

There are many other systems of driving a Fourdrinier. We have seen a machine still at work which is driven by belts and pulleys in the crudest manner, a manner, nevertheless, which used to find great favour and which, if we mistake not, was at one time the sole occupant of the field. In this, the speed of the whole machine could only be varied to suit a change in the quality of paper being made by knocking off the main drive pulleys and substituting a fresh pair. To obtain the requisite "draw" on the paper, that is, to vary the speed of each section of the drive to suit the contraction of the paper, layers of felt had to be wrapped round or taken off the subsidiary driving pulleys.

If the improved form of belt and rope drives such as we have described now hold the field, they are certainly threatened with a rival in the application of electricity to the purpose. There are at least two systems of electrical drive for Fourdriniers obtainable in this country—the Mather and Platt and the Bertram and Happer. We give a brief description of the latter system, the patent rights of which are held by James Bertram and Son, Limited, and Mr. J. R. Happer, of Linwood, Renfrewshire.

The objects sought in this, as in all other modern drives, are principally two. The speed of each section of the drive must be separately adjustable through a slight range to give the required amount of "draw" on the paper. The sectional speeds must be unitedly adjustable through a considerable range—say 1 to 10—to suit changes in the quality of paper being made. This united adjustment must leave the ratios among the sectional speeds unaltered. The Bertram and Happer system employs direct current. The positive and negative principal or outside mains feed positive and negative subsidiary or inside mains—see Fig. 63. These inside mains supply current to the armatures of the motors driving the various sections, each such motor having in its armature circuit a separate starting switch. The speed of any motor can be separately adjusted to give the required "draw" by varying the strength of the current used to excite its magnets. This exciting current is obtained from a separate inside main, and its strength is regulated by a suitable resistance A situated between this main and the magnet coils of each motor.



"THE ENGINEER" SWAIN SC.

FIG. 63.—Bertram and Happer Electrical Drive—James Bertram.

A portion of the lead between the positive outside and the positive inside main consists of the armature of a direct current generator. This generator is driven by a motor taking current from the outside mains. The current in the generator magnets is not only variable, but is reversible by means of a regulating resistance and reversing switch B. When the handle of the switch B is at "off," there is no resistance in the field magnet circuit of the generator. The current through the coils is therefore a maximum, and consequently the electromotive force developed by the generator is also the maximum. Owing to the manner in which the connections are made, this electromotive force opposes that in the outside mains. It is, too, greater than the other. The attendant turns the handle of the resistance B until the generator electromotive force is reduced to equality with that in the outside mains, a condition established when the voltmeters C and D read the same. He then closes the switch E, making the connection between the inside and the outside mains; but as the electromotive forces are opposite and equal, the electromotive force in the inside mains is zero.

Further movement of the handle of the resistance B decreases the retarding voltage and raises the voltage in the inside mains from zero upwards. When this inside voltage reaches the desired point each sectional motor is started up, and when all are running the paper is led through the machine. The speed of the whole may now be increased by turning the handle of the switch B still further, until it reaches the mid point, when the retarding voltage created by the generator falls to zero and the electromotive force in the inside mains is the same as in the outside. Further movement of the resistance handle reverses the current in the magnet coils of the generator and builds up an assisting instead of a retarding voltage in the generator. The voltage in the inside mains, therefore, rises above that in the outside until it reaches a maximum of something like double the outside reading. The generator is thus used to retard or to "boost" up the outside voltage. This part of the arrangement, we may say, is well known to electrical engineers.

It will thus be seen that when all is running the handles of the resistances A give a means of controlling independently the speed of each sectional motor, while the handle of the resistance B serves as a means of increasing or decreasing the speed of them all proportionately and simultaneously.

In Fig. 64 we give the arrangement of an actual machine driven by this system. Practical experience, we believe, has not as yet pronounced definitely on the relative merits, from the purely papermaking point of view, of the mechanical and the electrical forms of drive. It is apparent, however, that with the electrical system the back of the machine is kept remarkably clear of obstruction and is much more accessible than when the ordinary form of belt or rope drive is used. Further, the speed both of the whole and of the individual parts is as easily arranged to be controlled from the front of the machine as from the back, a statement which cannot always be made concerning a mechanical drive.

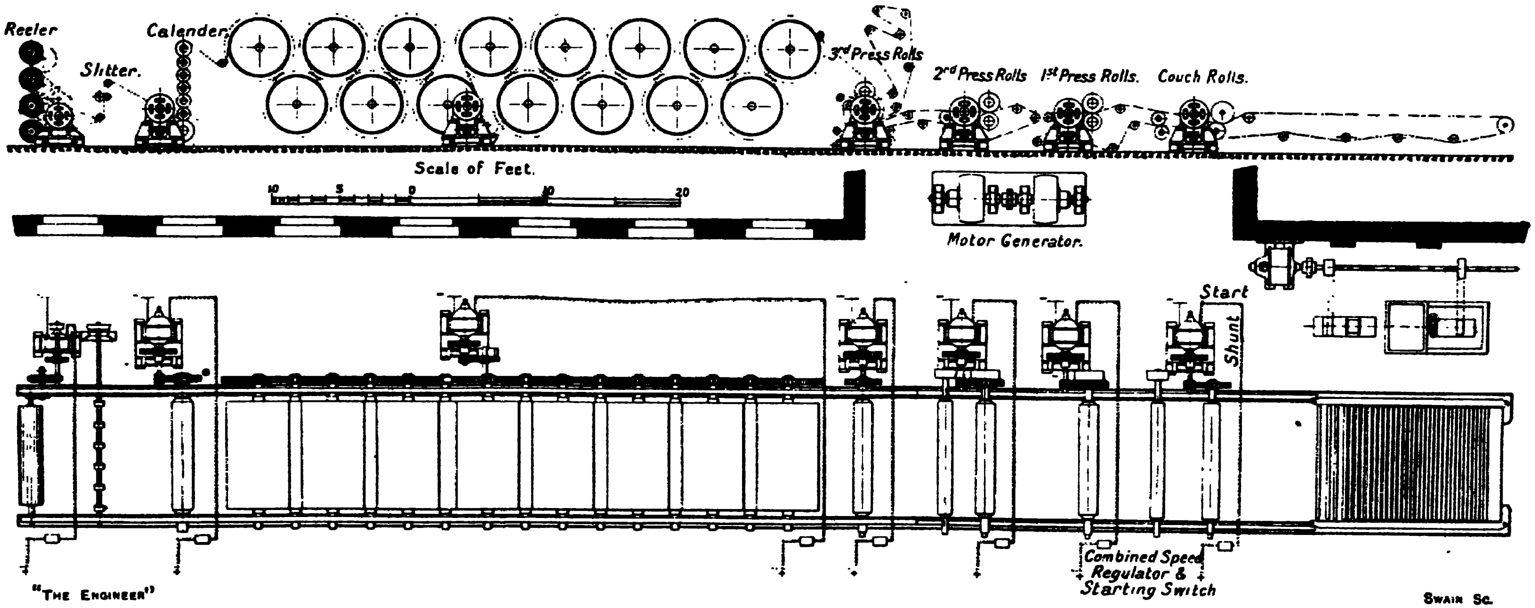


Fig. 64.—Electrically Driven Machine—Bertram and Happer System.

CHAPTER IX

DETAILS OF THE FOURDRINIER

HAVING described in the two preceding chapters the general lay-out of the Fourdrinier machine, and illustrated various methods of driving it, we now turn to consider some of its more important and more interesting details and auxiliaries. In this chapter we deal with the wire cloth and the wet end generally. In our next we will cover the dry end and the auxiliary machinery, while in the succeeding one we will discuss the construction and working of some typical strainers.

The wire cloth of a Fourdrinier is usually made of phosphor bronze. In an example before us, obtained from a wood pulp paper mill. the cross wires number 44 to the inch, as compared with 74 for the longitudinal wires. The interstices are, therefore, oblong in shape, with their longer dimensions parallel with the direction of travel of the cloth. It may be taken as fairly accurate that the interstices represent about 40 per cent. of any given area. At about $\frac{1}{8}$ in. in from each edge nine of the longitudinal wires are omitted, and in their place three strands of cotton are woven into the cloth to strengthen the edges. This cloth is a typical sample of that used in most mills, whatever the raw material or class of paper manufactured may be.

The wire is such an important part of the whole machine that we may well discuss its use somewhat fully. It may cost, say, from £30 to £40, and, as it is subjected to many influences tending to its destruction, its life is rarely very great—five to six weeks being about the average. Every effort should be made to preserve it and to get the last week of usefulness out of it. It may be remarked that it is because of the harmful effect which "anti-chlor" is known to have on the wire that many papermakers will not resort to this method of quickly removing all trace of the bleach from the pulp. The chief source of trouble is, however, a mechanical one. The cloth is driven by the lower couch roll, and in passing between these rolls and round the breast roll, &c., is bound to wear in time. If the wear were even all over its surface, its destruction from this cause would occupy a fairly considerable time. But it is not even. However carefully the cloth is handled and looked after, it cannot altogether escape being slightly puckered in places. The ridges developed may be very small and short, but they will receive a greater proportionate amount of wear than the rest of the cloth, and sooner or later they will be worn through. Skilful darning may enable the life of the cloth to be prolonged, but it is from the development of holes that the majority of wire cloths perish. Such holes do not mean simply that more fibre than usual is lost in the back water draining away from the cloth; the danger of their presence arises from the fact that they allow the fibre to come into direct contact with the metallic surface of the lower couch roll. The spot of fibre then clings to the roll and holes and rents in the web of paper result.

If we take a portion of wire cloth and pour a little water over it, we will find that capillary attraction holds up nearly the whole of the liquid on the top of the cloth. In practice this effect is overcome in great measure by the action of the large number of small tube rolls, on which, as we have seen, the working stretch of the wire cloth is supported. These tube rolls are rotated by the movement of the cloth, and on close examination it will be found that from the forward side of each one a continuous stream of water is coming away—see Fig. 65. Between the rolls no water, or an entirely insignificant amount, leaves the underside of the wire cloth. It will be found that if any tube roll be stopped rotating, as it can be, simply by holding one end with the fingers, the stream of water will immediately cease from it. The reason why the tube rolls thus assist to draw the water through the wire interstices is not very clear. It has been suggested to us that it turns upon the creation of a slight vacuum in front of the roll and below the cloth.

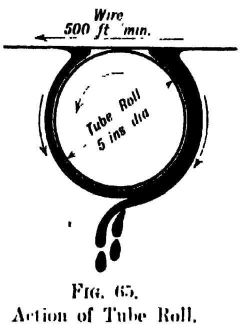


FIG. 65.
Action of Tube Roll.

The extraction of the loose water from the cloth, and therefore from the fibre, cannot be completed within a reasonable length by means of tube rolls, and hence we have the reason for the adoption of vacuum boxes. The construction of a typical vacuum box is shown in Fig. 66. It is a long, narrow chamber, roughly square in section and open at the top except for the presence of two bars which divide the whole length into three equal widths. The box is some 18 in. or so longer than the cloth is wide. Its ends are fixed, but at about 9 in. in from each is a screw adjusted false end, shaped to fit tightly the section formed by the box and the two bars. The material commonly employed is beechwood throughout; but mahogany, ebonite and many other substances have been, and are, used. Brass strips are usually affixed to the ends of the side walls, as shown in Fig. 66; and at the centre of the bottom there is an orifice for connection with the vacuum pump.

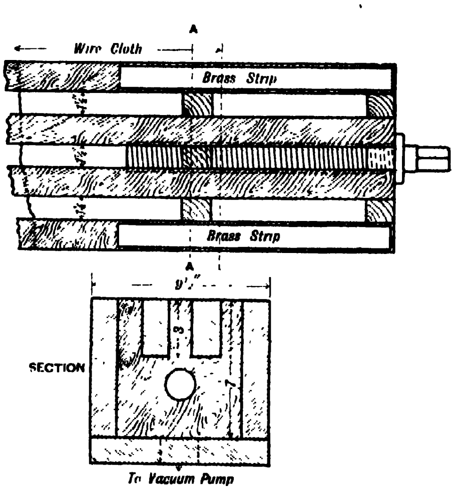


FIG. 66.—Typical Vacuum Box.

The false ends are adjusted to suit the width of the wire, and are placed so that the edges of the cloth just overlap them, as indicated in the engraving. The plane of the deckle strap, if continued forward to the vacuum box, may be represented by the line A A, so that the cloth to the left of this line is carrying fibre while the narrow strip to the right is free. If the width between the deckle straps is altered, the false end is correspondingly adjusted so that the vacuum area—the three slots between the false ends—is always covered by the fibre-supporting area of the cloth. The vacuum produced by the pump thus acts upon this covered area alone, and draws the remaining loose water out of the interstices and out of the fibre. The vacuum pump is, it will be seen, not allowed to waste power by drawing air in through the uncovered areas of the wire cloth. It is still possible, however, that it may draw air in between the false ends and the cloth. To prevent this the space between the false end and the real end is filled to the brim with water, and during the working is kept full by means of an india-rubber pipe delivering into it, the water being allowed to overflow over one of the brass-lined edges. If the flow of water is properly regulated, a very good water seal is thus established, while, owing to the presence of the false end, there is little danger of the water spreading over into the fibre-carrying area.

The fact that the wire cloth has to rub over the surface of three or possibly more of these vacuum boxes is responsible for much of the wear it experiences, and it is for this reason that various widely different materials have been used to make the boxes. The degree of vacuum employed varies a little with the custom of the mill and the nature of the paper being made ; but it may be said that 3 lb. to 3½ lb. is fairly common. A higher vacuum could easily be obtained, and so far as the making of the paper is concerned would probably give good results. But the amount is strictly limited by a practical consideration. The vacuum area of the box illustrated in Fig. 66 on a 100 in. machine works out at, say, 375 square inches. With a vacuum of 3 lb., and three vacuum boxes altogether, there is thus the equivalent of a load of about 1½ tons pressing the cloth down on the surfaces of the boxes. The cloth has to be driven against the friction produced by this load by the " nip " given it between the lower metal-surfaced couch roll and the upper felt-covered one. If the vacuum be too great, it may be impossible to drive the cloth. It may be noted that in some modern instances this difficulty, met with when it is desired to work with a high vacuum, is being overcome to a certain extent by driving the breast roll, thereby assisting the couch rolls to drive the cloth. It should be borne in mind, however, that, apart from this difficulty in the driving, the higher the vacuum the more rapidly will the cloth wear out in its movement over the box faces.

As the stuff flows over the lip of the breast box on to the wire cloth, the fibres have a natural tendency to set themselves with their lengths parallel with the flow. Were this permitted to pass wholly unchecked, the resulting paper would be disproportionately weak as tested at right angles to its length. Hand-made paper is as strong in one direction as the other because the vat-man, by shaking the mould in a certain manner, causes the fibres to felt together at all angles. The equivalent of this shaking motion has to be given to the wire cloth of a Fourdrinier, but it must be confessed that in no instance is it possible to secure the ideal result achieved by the hand maker. The best machine-made paper for which we personally have test results has a cross strength only equal to 66 per cent. of the strength lengthwise. Several others approach this figure, some are round about 10 per cent. less, others show a 40 per cent. ratio between the strengths, while one shows a ratio of only 34 per cent.

This departure from perfection is really not of much practical importance, for so long as the cross strength is sufficiently great, it rarely matters whether the strength lengthwise is equal to it or greater. The object of shaking may be said not to be to produce equality of strength, but to obtain a cross strength of the required amount.

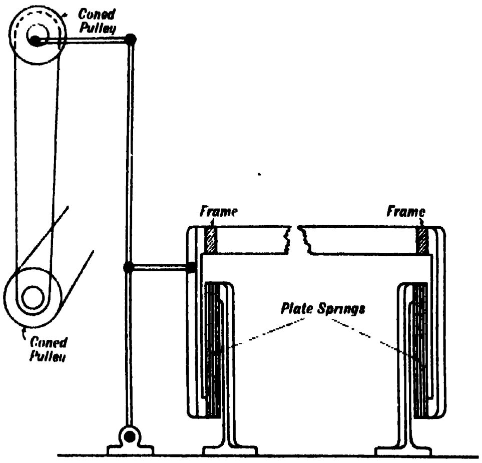


FIG. 67.—Shaking Arrangement.

Many methods of imparting the " shake " to the wire cloth have been tried. In practice what it works down to is this: The ends of the wire cloth frames next the couch rolls are supported on vertical pivot pins, while the breast roll ends of the frames are supported flexibly in such a way that they may be vibrated horizontally through an amplitude of about 1¼ in. at a rate of two or three hundred vibrations per minute. The shake thus gradually decreases in amplitude towards the couch roll end, at which point it becomes zero. A common method of supporting the wire cloth frames in order that this shake may be communicated to them is to hang the breast roll ends on bronze or other plate springs—see the sketch Fig. 67. The vibration is communicated to the frames by means of rods and a small crank on an overhead shaft provided with a plain—not stepped—belt cone whereby the speed of vibration may be varied. Fig. 68 shows diagrammatically another form of shaking arrangement whereby both the speed and the amplitude of the vibrations may be adjusted.

In other instances the frame is supported at short intervals throughout its entire length on "needles," that is to say, on struts having ball ends which engage sockets on the underside of the frame and on the floor.

To provide for the shake the frames, as we have said, work on vertical pins at the couch roll end. In most cases it will be found that these pins are themselves carried on members which are mounted on horizontal pins, so that, in effect, the couch roll end of the frame is supported on a universal coupling. The reason for this is that the breast roll end has to be capable of being adjusted vertically so that the wire cloth may be given the best amount of inclination to suit the quality of paper being made.

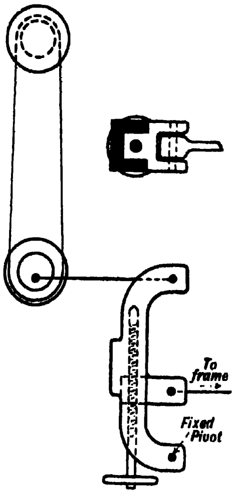


Fig. 68.
"Shake" Adjustment.

It may be explained here that some time ago patent rights were granted in this country to a German for a method of working in which the breast roll end of the frame could be raised by as much as 14 in. or 15 in. above the other. The granting of the patent was contested successfully in the Courts, for it was established that for many years it had been the common practice in certain mills to work with the wire cloth in other than a horizontal position, although the elevation given to the breast roll end was at that time not usually as great as that contemplated in the patent.

If the stuff as it passes from the breast box on to the cloth be observed, it will be seen that for the first 4 ft. or 5 ft. of its travel on the cloth the flow forms into waves fairly persistent in size and position, but gradually dying out towards the end of the length named. The explanation is to be found in the fact that it takes this distance of 4 ft. or 5 ft. before the velocity of the flowing stuff can rise to the speed of the wire cloth. As soon as the two are equal, the waves die out and the stuff spreads evenly over the surface of the wire. It might be possible to overcome the difficulty by giving the stuff a " head " before it flowed on to the wire, thus increasing its initial velocity. In practice, however, it seems to be found best to increase the velocity by causing the stuff to flow downhill. This is the explanation of why the breast roll end is arranged to be made higher than the other. It is clear that if the wire cloth be kept horizontal it will take so much longer before the wave formation dies out, or, alternatively, by so much will the speed of the cloth have to be reduced. Either an excessive length of the wire cloth has to be allowed for the dying out of the waves or the output of the whole machine has to be considerably reduced. The important effect of elevating the breast roll end of the wire cloth is thus apparent. In the case of the *Daily Telegraph* 134 in. machine referred to in our seventh chapter, the elevation of the breast roll end of the wire frame above the couch roll end can be adjusted between zero and 6 in.

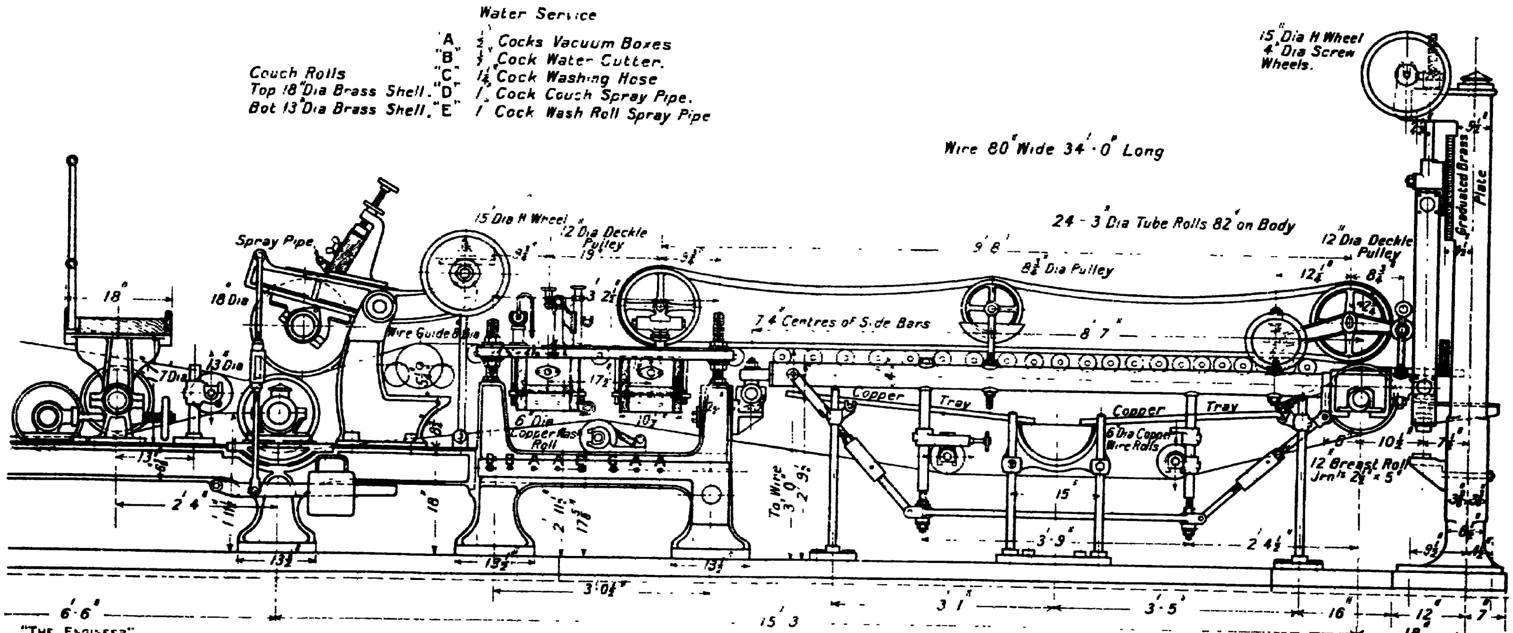
A detailed drawing of the wet end of a machine recently constructed by James Milne and Son, Limited, of Edinburgh, is given in Fig. 69. This drawing, besides showing several other interesting points, illustrates an improved method of supporting the breast roll end. The form of support adopted provides both for the accommodation of the shake and for the elevation of the breast roll end, of which we have spoken above. The side bars of the wire frame consist of thick brass tubes 4 in. in external diameter. Both these tubes are strongly trussed, for they are not supported from the ground in any way except at the ends. At the forward end each bar is separately supported on a two-pivot arrangement of the type already referred to. At the breast roll end two cast iron pillars are bolted to the bed plate, and each of these supports a hand-adjusted sliding head which works against a graduated scale on the pillar. Two plate springs 4 in. wide by $\frac{1}{8}$ in. thick connect each sliding head with the end of the corresponding tubular side bar.

Small adjustments of the inclination can with this arrangement readily be made while the machine is running. If the elevation required is considerable, the machine has to be stopped, for it will then be necessary to adjust the vacuum boxes to suit the new position of the wire cloth. The two vacuum boxes are supported by a pair of horizontal bars, the ends of which embrace standards provided with a screw-thread and nuts. By these means it is possible to incline the vacuum boxes similarly to the wire cloth. The dandy roll brackets and the forward pair of deckle strap pulleys are carried on the vacuum box supports. The intermediate and rear deckle strap pulleys and the breast roll are carried on the tubular side bars, while on the trussing beneath these bars two of the guide rolls for the return of the wire cloth are journalled. All these parts, therefore, partake of the adjustment of the inclination. The copper "save all" tray beneath the wire cloth is separately supported from the ground and remains stationary.

Before leaving Fig. 69, we may call attention to the method which it shows of adjusting the pressure of the upper felt covered couch roll against the lower brass-sheathed roll. It will be seen that the pressure is produced by weighted side levers and is under the control of a hand wheel whereby it may be relieved when the machine is idle. On the top of the upper roll there is to be seen a wooden scraper or "doctor," which, together with a water spray, serves to keep the felt surface clean and free from adhering particles of fibre. A cleaning arrangement for the wire cloth on its return side, consisting of a water spray, a 6 in. copper roll and a wooden scraper, will be noticed beneath the vacuum boxes.

By reference to Fig. 69, it will be seen that the wire of a Fourdrinier passes at one end round the breast roll and at the other round the lower couch roll, that on its top stretch it is supported by a series of tube rolls and the upper surface of the vacuum boxes, and that on its lower or return side it passes over or under two or more wire rolls and usually a wash roll. Of all these rolls not one is provided with end flanges between which the wire might run and by which it might be held from moving from one side to the other. The vacuum boxes are likewise not provided with flanges. So far as we know, there is no mechanical difficulty to be faced in providing these flanges, but they would be quite unpractical, and on no machine which we have seen or know of are such flanges to be found.

Yet the tendency of the wire to run or creep over towards one side or the other is quite marked, and must, of course, be prevented at all costs, or the machine would at once break down. The slightest irregularity in any of the rolls either in their diameter



"THE ENGINEER"

SWAIN SC.

FIG. 69.—Wet End of a typical Fourdrinier—James Milne.

or in their alignment, and many other causes, will result in the wire cloth leaving its central position. In practice it is found that the wire has a tendency one moment to move towards one side of the machine and the next towards the other.

The simplest and best method of preventing this objectionable habit seems to be not to provide flanges on the various rollers but to fit a device known as a wire guide. This device acts in conjunction with a guide roller over which the wire passes after leaving the last vacuum box and before reaching the couch rolls—see Fig. 69. The wire is driven by, and—in nearly every instance—solely by, the lower couch roll. It is found quite possible and to be best to guide the whole round of wire from a point situated on the upper stretch close to the couch rolls.

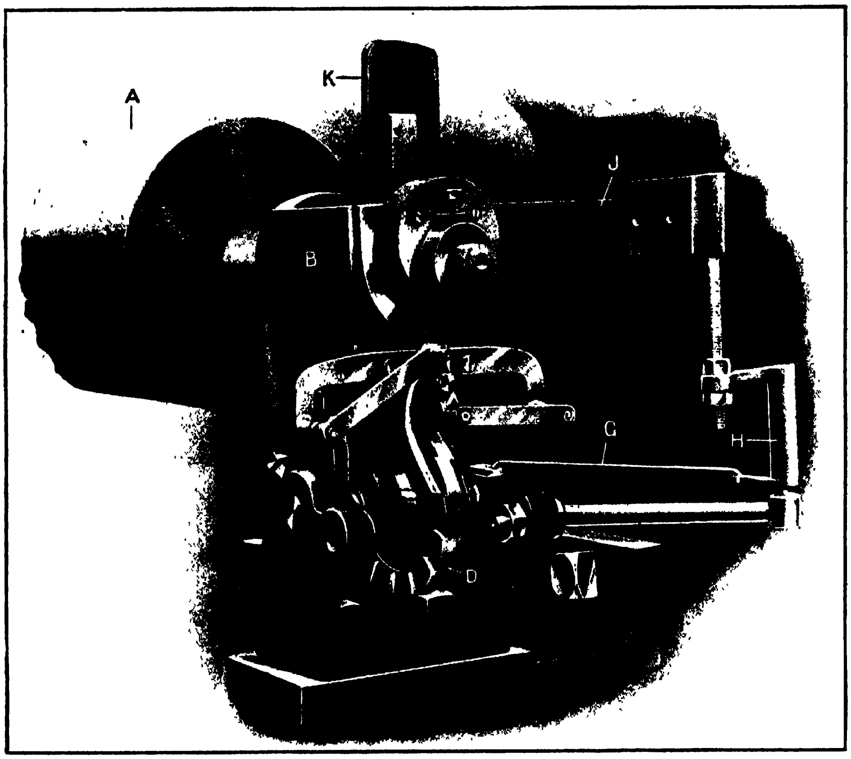
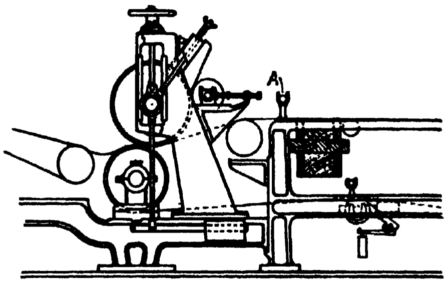


Fig. 70. The Sciennes Wire Guide—Bertrams'.

At the guide roll the wire hitherto travelling in a substantially horizontal plane dips down at a fair angle to the couch roll. The spindle carrying the guide roll on the far side—as seen in Fig. 69—is mounted in a bearing which can swivel upon a central vertical pivot. The front journal can move horizontally either to the left or right. The guide roll can thus be set at an angle across the machine on either side of its central or neutral position. With the guide roll in the neutral position, let the wire creep over to the front of the machine, that is, the near side in Fig. 69. Move the front journal of the guide roll to the left. The wire will respond by creeping back to its central position. Similarly, if the wire creeps over towards the back of the machine a movement of the front guide roll journal to the right will bring the wire back to its normal course. The reason for this action of the guide roll is clear on a little reflection.

According as the front end of the guide roll is moved to the left or right, so is the tension increased or decreased in the front edge of the wire cloth relatively to that in the back edge. The wire tends to move over towards that side in which the tension is least.

The object of a wire guide is to effect automatically the movement of the guide roller so as to check the creeping of the cloth in the above manner. There are many forms of automatic wire guides on the market. We illustrate one form, known as the "Sciennes" wire guide, and made by Bertrams, Limited. In Fig. 70, A is the front end of the guide roller, the horizontally movable journal of which is contained within the bracket B. This bracket, suitably supported, has a forked lower end through which a right-hand square-threaded spindle C passes. Between the forks a tapped wheel D works on the spindle. The edges of this wheel are serrated as shown. A double pawl piece, in the form of a horseshoe, is designed to engage the serrations. This pawl piece is constantly reciprocated in a vertical direction by means of the parallel motion E and an excentric F fixed to the end of the guide roll spindle. The pawl piece is connected by a stout piece of brass wire G to one arm of a bell-crank lever H, the other arm of which supports on a screw a flat bar of wood J. This bar carries a vertical brass spade K situated close up to the edge of the wire cloth.



When the wire creeps over towards the front, it presses on the spade K and through the members H and G throws the right-hand pawl into engagement with the serrations on its side of the wheel D. The reciprocation of the pawl piece then causes the wheel to rotate and move on its screw towards the left, carrying with it the bracket B. The bar J extends right across to the other side of the wire and there carries a second spade. This spade causes the left-hand pawl to come into action with a reverse result, when the cloth creeps towards the back of the machine.

When a Fourdrinier machine is being started up either at the commencement of a week's run or after an accidental breakage of the web, it is very desirable in order to facilitate leading the paper through the rolls and over the cylinders that the end of the web should have a "tail end," that is to say, should be brought to a point so that the machine-man may readily take hold of it. An apparatus, patented some considerable time ago by Mr. John Greig, the manager of the *Daily Telegraph* mills at Dartford, and made by Bertrams, Limited, of Edinburgh, permits this tail end to be readily formed by mechanical means.

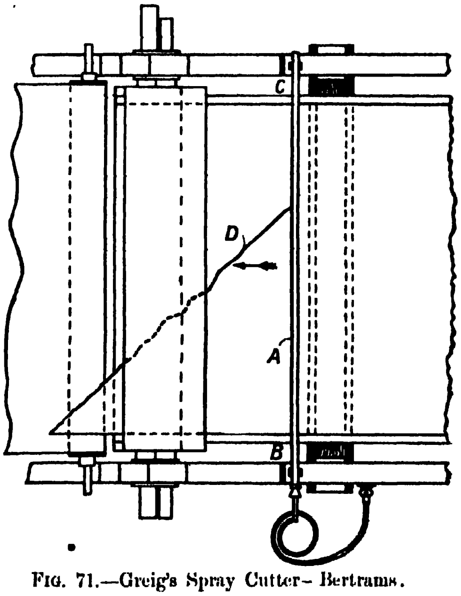


FIG. 71.—Greig's Spray Cutter—Bertrams.

The apparatus referred to is known as Greig's spray cutter, and is illustrated in position in Fig. 71. A brass tube A is fixed across the wire frame at a point just after the last vacuum box and before the couch rolls. This tube is slotted from end to end on the underside and guides and supports a sliding nozzle, the point of which lies at about 2½ in. above the surface of the paper as it passes forward below the pipe on the wire cloth. The nozzle is connected by a small-bore rubber hose-pipe with the water supply. When it is required to form the tail end, water is turned on and the nozzle is pushed across the machine by means of the hose-pipe in the direction from B to C. The paper being as yet quite soft, is cut diagonally, as at D, by the force of the jet issuing from the nozzle. The tail formed can be made broad or sharp by varying the speed at which the jet is traversed within the brass pipe.

A slightly different form of water cutter, but one acting on the same principle as the above, is indicated in Fig. 69.

The leading rolls over which the paper passes at the wet end present one of the many minor problems to be solved by the designer of the perfect Fourdrinier. It is obvious that as the paper passing over these rolls is as yet not dry and is, therefore, weak, it is not altogether desirable that we should trust for their rotation solely to the pull of the paper. Ball bearings help considerably, and are commonly adopted. But the undriven leading roll, even when so provided, is a source of some trouble when the web is being led through the machine at the start of a fresh spell of work. The rotation of each roll has to be started by hand for the strength of the paper may not be sufficient to provide the pull required during the period of acceleration, although it may be sufficient to keep the roll rotating once it is started.

Under the circumstances it is natural to find that many attempts have been made to drive the leading rolls by power. It might be thought that, if they were driven positively, as by gearing, from the adjacent press roll or other driven part of the wet end, matters would prove satisfactory. Such, we understand, is not the case, and most attempts to drive leading rolls positively have proved failures.

Under Bertram and Milne's patent, Bertrams, Limited, have introduced a form of power driven leading roll for which complete success is claimed. This roll is illustrated in Fig. 72. It consists of a brass or copper tube provided with removable ends and mounted loosely on a thorough-going spindle. This spindle is driven by belt at a slightly higher rate than would be required to give the roll if it were fixed to the spindle a peripheral speed equal to the speed of the paper. The roll is rotated solely by the friction produced on the spindle by its own weight. When the paper is being led through, the end of the web is laid on top of the leading roll. This at the moment is rotating as fast as its spindle and therefore pulls the slack of the paper forward.

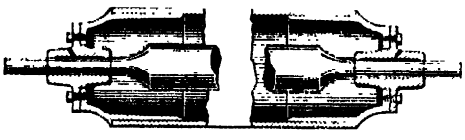


FIG. 72.—Power-driven Leading Roll—Bertrams'.

As soon as the slack has been disposed of, the pull in the paper reduces the speed of the roll against the friction drive to the appropriate peripheral amount, whereupon the roll settles down to assisting the paper along. This type of roll, it is claimed, is particularly suited for high-speed machines and for machines turning out thin and tender paper. Existing rolls, we understand, can readily be altered to this system.

CHAPTER X

DETAILS OF THE FOURDRINIER (*continued*)

THE stuff chests, to which the pulp is delivered from the beating or refining engine and whence it is drawn as required by the Fourdrinier, are usually at least two in number and are sometimes constructed of concrete. More commonly they are of cast iron, as shown in Figs. 73 and 74, where sets built by James Milne and Son, Limited, of Edinburgh, are shown. The joints between the sections of the tanks are usually made with Portland cement, and the inside is finished off with cement and tiles. As the pulp, if let to stand, will settle, agitating means have to be provided. As shown in Fig. 73, this may consist of a screw propeller fitted to the end of a vertical shaft, driven through bevel gearing, and a clutch from a horizontal shaft serving both chests. The propeller runs at seven to nine revolutions per minute, and each absorbs not more than two horse-power. The end of the propeller shaft in Fig. 73 is supported in a simple footstep bearing fixed to the bottom of the tank. In the chests illustrated in Fig. 74, the footstep bearing is at the bottom of a pipe which extends upwards round the shaft to a point above the level of the pulp, thereby excluding water from the bearing. In this case the agitator is not a propeller but consists of two arms depending from a cross tree fixed to the shaft just above the pipe. In other examples using a propeller agitator, the central shaft will be found to extend through a packing gland in the foot of the chest and to be supported in an external footstep bearing. In others, again, the shaft may be suspended from an overhead ball thrust bearing. The chests illustrated are provided with copper outlet pipes of

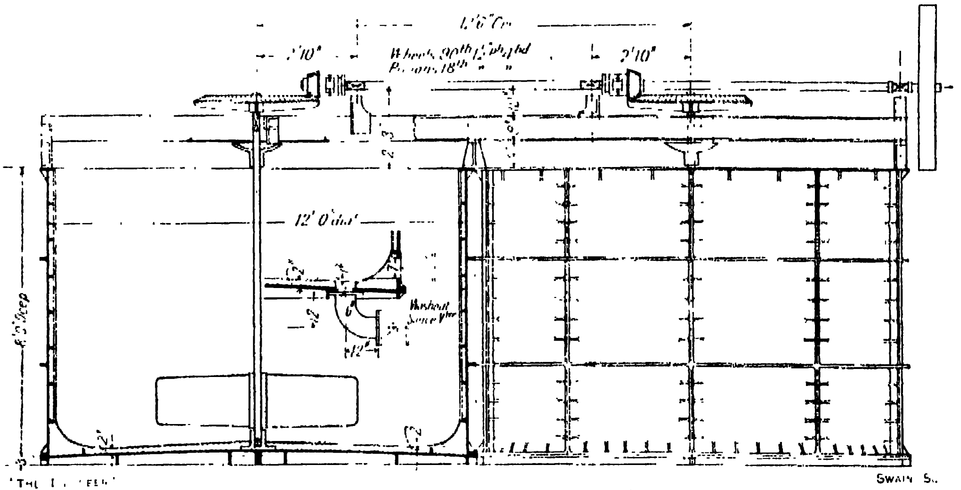


FIG. 73. Cast Iron Stuff Chests—Milne.

7 in. bore or thereabouts and with suitable wash-out valves draining from the lowest point of the cambered bottom.

What the papermaker calls " back water " is the liquid which drains off from the pulp through the wire cloth. A further supply of back water is extracted from the sheet of fibre by the vacuum boxes. The liquid is not pure water by any means. It contains quite a perceptible amount of fibre, together with a more or less equivalent proportion of the sizing and loading materials added to the pulp in the beaters. Efforts to save this material should, if possible, be made in the interests of economy.

One method of doing so, to a very considerable extent, is by the use of stuff-catchers or economisers. A stuff-catcher made by James Bertram and Son, Limited, under the Füllner patent, is illustrated in Fig. 75. The back water is collected by suitable wooden troughs, and is pumped up to a high-level back-water box shown at A. From this, as much of it as may be desired can be drawn off to dilute the flow of fresh pulp passing through the mixing box B on its way to the sand table C. In this way a fair proportion of the back water is returned direct for a second passage over the wire cloth.

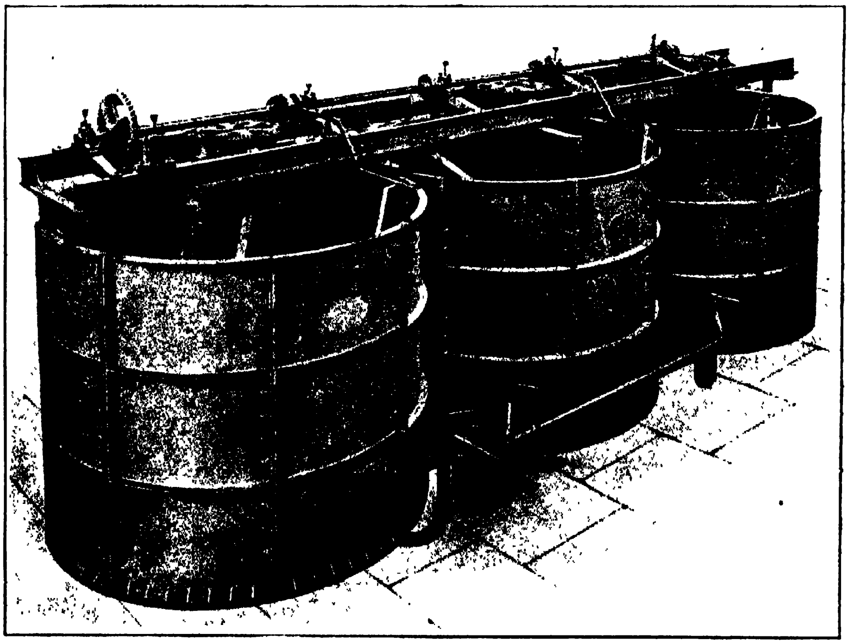
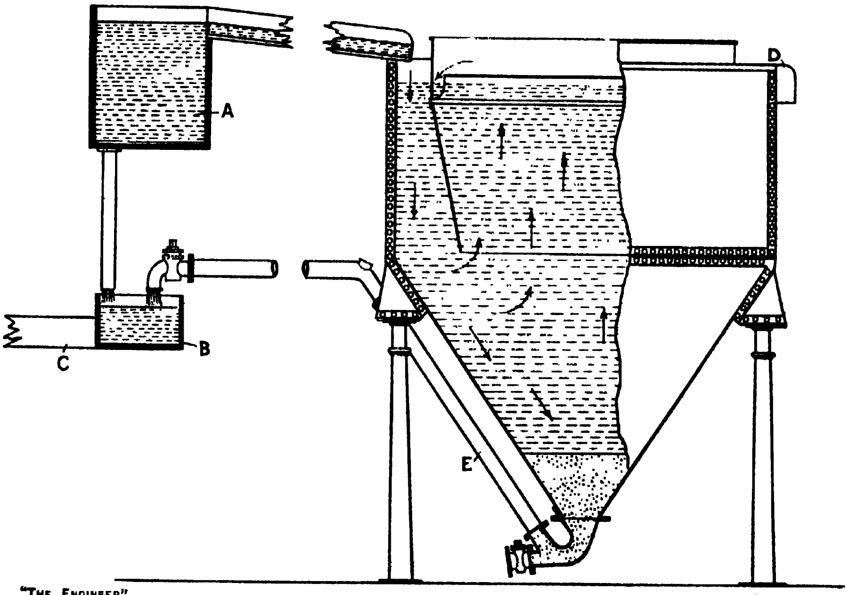


FIG. 74.—Cast Iron Stuff Chests—Milne.

The bulk of it, however, overflows the box A and runs down into the stuff-catcher—a cylindrical coned vessel commonly made of sheet copper. In this it is allowed to settle. The clear water ascends within a conical central baffle from a circular internal lip near the top of which it flows off by way of the outlet D. The thick stuff at the bottom under the hydrostatic head of the water within the vessel can be drawn off by way of the pipe E and discharged as a continuous stream into the mixing box B.

We are informed that several mills using these stuff-catchers have reported an increase of as much as 2½ per cent. in the output of paper since they adopted them.

The average of a number of tests conducted at the Springfield Paper Mills, Bolton, has, we understand, shown that in a gallon of water going into the economiser there were 120 grains of fibre, &c., while in a gallon of the outlet water the quantity was about twenty grains. It may be suggested that in the back water there will be a higher percentage of sizing and other materials relatively to the fibre than in the original pulp, so that when the caught stuff is returned to the mixing box the result is to deliver to the Fourdrinier a more richly charged pulp than that delivered from the stuff chests. We believe this is actually so, and that tests reveal 2 to 3 per cent. more residue in the paper when the economiser is in use than would otherwise be the case. Clearly, then, the economiser results not only in an increase in the output of paper but can be the means of saving quite a respectable amount of chemicals in the course of a year.



"THE ENGINEER" SWAIN Sc.

FIG. 75.—Stuff Catcher or Economiser—James Bertram.

A considerable number and variety of pumps are required in a paper mill. In nearly every case a paper mill, like a brewery, pumps its own water supply. In the process of preparing the pulp, as we have seen, pumps are frequently used in the carriage of the stuff from one machine to another, although as far as possible gravitation is taken advantage of for this purpose. The bleach liquor after preparation, usually on a lower floor, has commonly to be raised to a higher level to reach the potching and bleaching engines. For this purpose the use of pumps is being discarded by some, as it is found practically to be impossible to construct them so that their parts shall successfully resist the corrosive action of the liquor. The simplest solution is to prepare the bleach on the floor above that on which it is to be used. The majority of mills, however,—for some reason which is not quite clear—have their bleach mixers on the ground floor, with the potching engines above. At one mill so arranged which we have visited, the liquor is raised to a storage tank on the floor above by admitting it to an air-tight vessel and delivering compressed air on top of it.

Of the pumps connected more directly with the Fourdrinier there are in general four kinds, namely, for the vacuum, for the stuff before it reaches the machine strainers, for the back water and for any excess water—more or less pure—which may originate at the wet end. The back water and the excess water pumps are sometimes of the centrifugal type. The stuff pump is usually of the plunger type, as it has to handle thick material. The vacuum pump is also commonly of the reciprocating type. Three pumps representing modern practice are herewith illustrated.

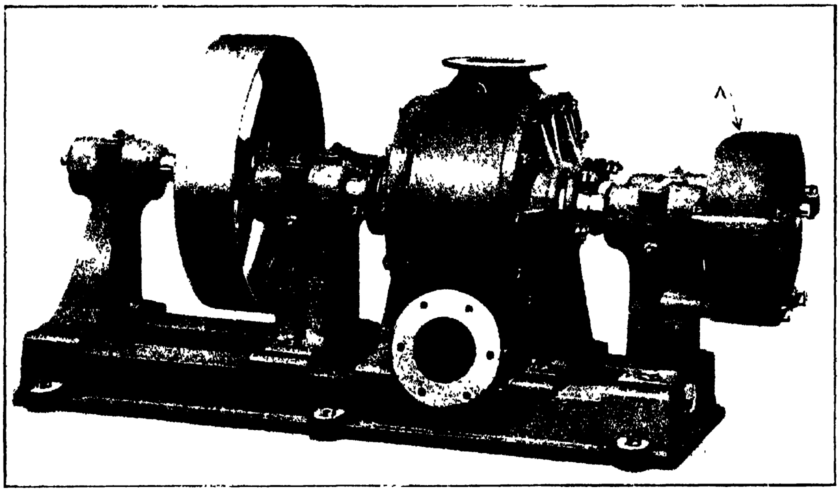


Fig. 76. Rotary Vacuum Pump—Milne.

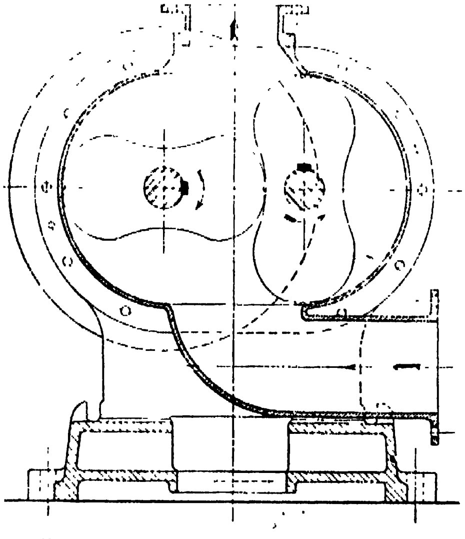


Fig. 77.—Section of Milne's Vacuum Pump.

There are many designs of vacuum pump on the market which are suitable for working in conjunction with Fourdrinier vacuum boxes. In Fig. 76 we illustrate one form, as made by James Milne and Son, Limited. As shown by the cross section—Fig. 77—the internal arrangement reminds one of a Root's blower. In the smaller sizes the two shafts are coupled together, as shown at A in Fig. 76, by a pair of cut steel spur gears situated at the end remote from the belt pulley. In the larger sizes a second pair of such gear wheels is added at the point where the belt pulley is shown in Fig. 76, the pulley being then moved over to the left so as to overhang the outer shaft bearing. The largest size of this type of pump weighs about four tons and is capable of displacing about 780 cubic feet per minute. The shafts carrying the octoids are of greater diameter, for they have to resist the shocks produced by the incidental call on the pump to deal with water, or water and air mixed. These pumps are sometimes made entirely of brass, with brass rotors, or they may be lined with this metal.

Another form of vacuum pump by the same makers is illustrated in Fig. 78. This is of the horizontal duplex double-acting piston type, and is particularly intended for running with large, fast machines. Two sizes are made, namely, 14 in. diameter by 12 in. stroke, and 18 in. by 18 in. There may be three of these pumps for each machine in the mill. An exactly similar design of pump is made for dealing with the backwater.

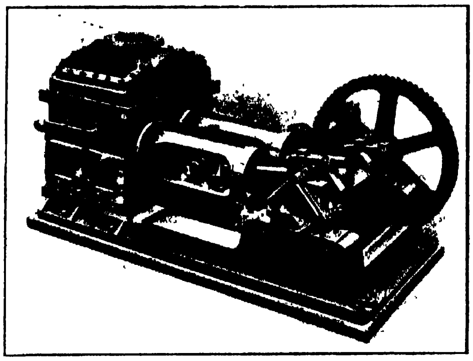


Fig. 78. Vacuum or Backwater Pump—Milne.

For handling the stuff on its way to the machine, pumps are usually required. An example of such a stuff pump, as made by Messrs. Milne for some of the largest "news" mills in this country, is illustrated in Fig. 79. This set has three plungers, each 12 in. in diameter with a 12 in. stroke. The inlet and outlet valves are arranged to be very readily accessible, as is necessary when we have to deal with a liquid of the nature implied. There are usually two sets of these pumps for each Fourdrinier machine.

We now return to the machine itself and discuss one or two of the details connected with the drying cylinders and the dry end generally.

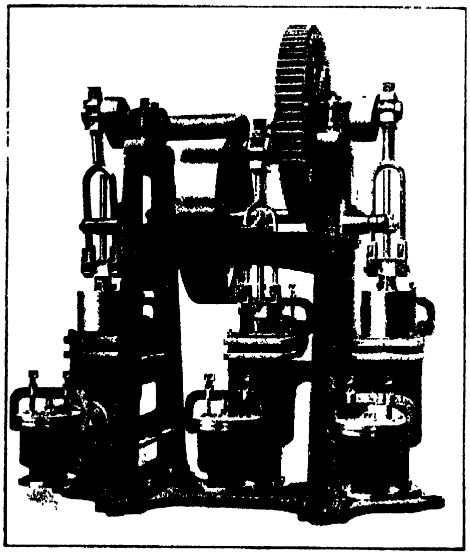


Fig. 79. Stuff Pump—Milne.

The design and construction of the drying cylinders are matters requiring very careful attention. The pressure of the heating steam commonly used is not great; indeed, the exhaust of the engine driving the Fourdrinier is sufficient. But the steam has to be admitted into the interior of the drying cylinders and the water of condensation extracted therefrom without a trace of moisture leaking to the outside, where it would at once spoil the paper being made.

The cylinders are ordinarily made of cast iron, and, were it practicable to cast the barrel, the ends and the trunnions all in one piece, it would no doubt prove best in practice. In default of this, the ends are commonly bolted on to the barrel—a practice which cannot be regarded as ideal, although with careful workmanship and upkeep it no doubt answers its purpose.

The patented design of end adopted by James Bertram and Son, Limited, in many recent instances is illustrated in Fig. 80. The barrel, a short distance in at each end, is formed with a flange having a ring turned on it. Outside this flange the inner surface of the barrel is coned and roughened, as shown. The cylinder end is cast in one with the trunnions, and is turned to fit tightly on to the ring of the flange inside the barrel. Its edge is coned and roughened like the adjacent portion of the barrel. The end having been driven into position, the conical annular space between the roughened surfaces is caulked up with a preparation of iron rust, which forms a solid ring on setting. The fit at the ring, the contact between the faces and the filling material form three separate defences against leakage, while the conical form of the roughened surfaces prevents the end from being blown out under the mild pressures in use.

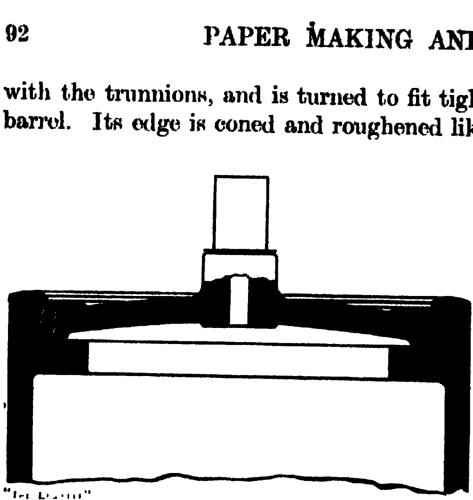


FIG. 80.—Drying Cylinder End—James Bertram.

Manholes have, of course, to be provided in the cylinder ends. The form adopted by the same firm is shown in section in Fig. 81. Two oval covers, one inside and one outside, are employed. The connecting studs are well away from the joint and do not pass through the inner cover into the steam space.

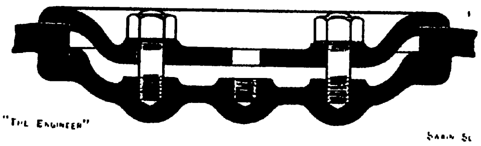


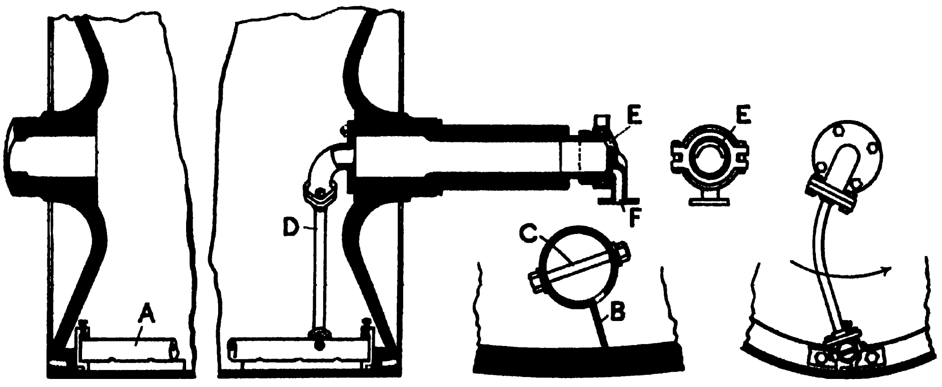
FIG. 81.—Manhole Covers—James Bertram.

Generally speaking, it is a good deal more difficult to arrange for the satisfactory removal of the condensed water from the drying cylinders than to admit the steam. The obvious difficulty is to draw off the water without allowing some portion of the steam to escape.

The quantity of steam used varies a good deal with the design of the machine, the quality of the paper being produced, the humidity of the atmosphere and other factors. But to give an approximate idea of the quantities involved, we may say that for every pound of paper produced we could expect to find three pounds of exhaust steam consumed in the drying cylinders. Let us take the case of a machine producing 1000 lb. of paper per hour and having eighteen 48 in. by 100 in. cylinders running at ten revolutions per minute—or 125 ft. per minute. The steam consumption works out at under 3 lb. per minute for each cylinder, or, say, a quarter pound per revolution. This is the amount of condensed water which has to be removed, and, small as it is, it no doubt gives a considerable amount of trouble.

One method—that used by James Bertram and Son, Limited—is illustrated in Fig. 82. In this, a brass pipe A stretches across the full length of the cylinder. Its ends are stopped up and are held in suitable brackets attached to the inside of the internal flange already referred to in connection with Fig. 80. A longitudinal slot is cut in the pipe, and into this is inserted a tongue B of sheet copper. Bolts C pass through the pipe and close the slot so as to hold the tongue firmly. There is no movement of the pipe and tongue relatively to the cylinder. They merely form a baffle or pocket which scoops up the water during the lower half of the rotation. During the upper half of the rotation the water passes through holes cut along one edge of the slot into the pipe, and thence down the pipe D into the hollow trunnion. At the end of the trunnion there is fixed a cap in which a semi-circular port E is cut. This cap works within a fixed gland provided with an exhaust connection at F. For half of each revolution of the drum—the upper half—the port E opens the passage F to the condensed water. During the lower half of the revolution the exhaust passage is closed and no uncondensed steam can escape through it.

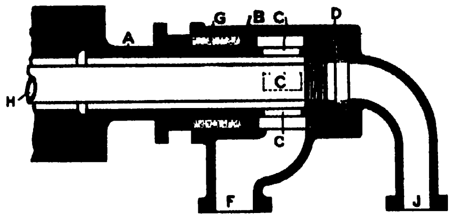
Quite a different system is adopted by Bertrams, Limited. This firm's practice, under Milne's patents, is to make use of the one trunnion for both the admission of the heating steam and the exhaust of the condensed water and to employ a lifting bucket only 15 in. or so wide instead of making its length equal to that of the cylinder.



"THE ENGINEER" SWAIN SC.

FIG. 82.– Water Lifter for Drying Cylinders—James Bertram.

The connection at the trunnion end, as used in this system, is shown in section in Fig. 83. The stem A is fixed to the trunnion end and carries a ring B of gun-metal to serve as an abutment for the packing G. Beyond the ring four ports C are cut in the stem, while its end is screwed to receive the internal pipe H. A white-metal bush D fits over the end of the stem and is rotated therewith, the connection being made by means of projections on the one and recesses on the other. The whole is enclosed in a stationary casing provided with a steam inlet F and an exhaust outlet J. The pipe H is thus constantly in communication with the exhaust branch J, while the annular space outside it is also constantly open to the steam supply through the ports C and the chamber between the ring B and the bush D.



"THE ENGINEER" SWAIN SC.

FIG. 83.– Steam Connection—Bertrams'.

The whole arrangement is shown in place in Fig. 84. The exhaust pipe H is connected by a radial pipe with the water-lifting bucket, the section of which is shown at K. From this section it will be gathered that the arrangement works equally well whether the cylinders run in one direction or the other. A trap L prevents any water in the horizontal pipe H from running back into the cylinder when the bucket descends through the lower half of its revolution. The external exhaust branch J leads into a trap M of the float type. The trap casing comprises two main chambers separated by a wall which reaches almost to the underside of the top cover. Into the smaller chamber the exhaust pipe leads, and its end here is always water-sealed so that no steam can escape past it. The float is open at the top, and is provided with projections round its lip, so that even in its highest position a passage way for water is left into its interior. The fixed tube through the centre of the float has openings near its lower end, through which water may pass from the interior of the float into the discharge main. The condensed water flowing over the lip of the larger chamber raises the float and causes it to close the openings in the central pipe. More water coming in flows into the interior of the float, weighs it down and escapes through the openings to the exhaust main. It is claimed that this trap is sensitive to a variation of $\frac{5}{8}$ in. in the height of the water level, between which limits it will open and shut.

It may be noted here that the temperature of each cylinder—and therefore the pressure of the steam within it—is usually adjusted so as to increase slowly and progressively from the first to the last cylinder. If the paper be dried too suddenly, the sudden contraction will cause it to cockle or blister, as the papermakers call it. Hence the gradual drying aimed at. By the time the paper reaches the last drying cylinder, it is so hot that the hand cannot comfortably be placed on it. On its passage through the calender immediately after, the "fire" is sometimes taken out of it by causing cold water to circulate through certain of the calender rolls.

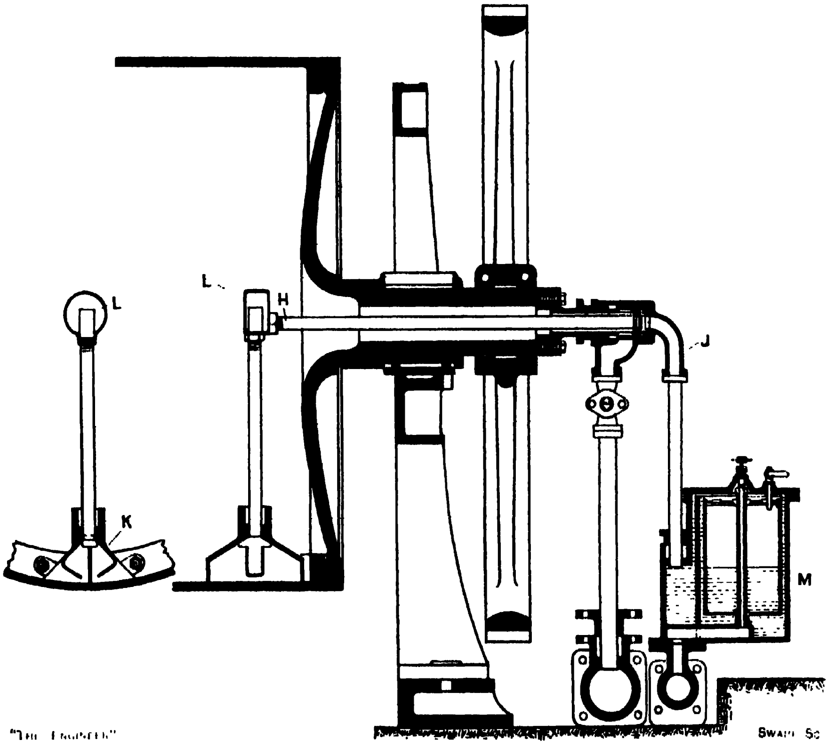


FIG. 84.—Water Lifter, Steam Connection and Trap—Bertrams'.

An interesting point connected with these same calender rolls may also be mentioned here. The rolls may be, say, 20 in. in diameter, while the speed of the paper may be 250 ft. per minute. Let us suppose that the diameter of the rolls at the middle increases owing to thermal expansion by one-thousandth of an inch while the diameter at the ends remains constant. The circumference of the rolls at the centre has increased by one two-hundredth per cent., therefore the length of paper passed between them at this point per minute is not 250 ft. but 250 ft. 0·15 in. Reels of paper 8000 yards long are commonly turned out for newspaper purposes. Such a reel, if calendered on these rolls, would be 14 in. or so longer at the centre than at the edges. It hardly sounds worth talking about, but our calculation cannot take account of all the conditions and undoubtedly errs on the side of modesty. Actually, however, the increase of length, while of little moment in itself, produces a visible result. Each foot of paper has to accommodate its own increase at the centre. The surface of the paper, therefore, buckles by an amount surprisingly great for the small linear increase involved.

In practice, differential expansion of the calender rolls may prove a source of serious trouble for the reasons we have attempted thus to indicate. At a certain mill which we recently visited, we saw the difficulty being overcome by arranging for the delivery at will of a blast of cold air on to the expanded part of any of the rolls at whatever point in the length it was situated. We believe the system referred to is patented, but we have been unable to discover the maker's name. The same idea is to be seen applied to the calender rolls of the *Daily Telegraph* 134 in. machine.

The endless bands of felt employed in connection with the drying drums are worthy of some attention. They have, of course, to move with the paper and drums, and are used with the object of holding the web in close contact with the cylindrical metallic surface, so producing the requisite amount of friction between the two for driving and leading-through purposes which otherwise would have to be obtained by applying a considerable amount of tension to the paper itself.

In arranging the felts proper provision has to be made for ensuring that they are kept fairly dry, that the tension in them may be adjusted to the right amount, and that they may run stretched in the transverse direction and not be allowed to pucker up. The felts naturally absorb a fair amount of moisture from the paper. In some cases this is removed from the felts simply by relying on the heat passing from the drying cylinders through the paper. In other instances, each felt on its idle return side is made to pass round a separate drying cylinder of similar or the same design as that of the paper cylinders. There is usually one such cylinder for each of the felt bands. They are mounted above the main cylinders on the same frame for the felts serving the upper row, and below the floor level for the felts of the lower row.

The proper degree of tension is applied to the felts by means of suitable hand-operated "stenting" rolls mounted slidably in guides on the main frame. To maintain the proper degree of transverse stretch in the felt, one or more of the rolls over which it passes may have raised on its surface a right hand knuckle thread at the right-hand end, and a left-hand thread at the other. These threads, when the roll is rotating, naturally tend to force each edge of the felt outwards and so keep it from creeping into puckers.

If Fig. 54, page 57, is carefully studied, it will be found that the first two drying cylinders are not embraced by a felt band. In some cases three of the cylinders are left unfelted. In others, again, it will be found that, while the first or the first and the second are unfelted, the succeeding cylinder has a smaller proportion of its circumference thus engaged than the remainder. Occasionally all the cylinders are felted, but the commoner practice is the other way. The reason is somewhat curious. It is found that if the earlier cylinders are fully felted, the china clay, &c., in the paper very quickly accumulate on their surface to an objectionable extent. This is due to the paper being still fairly damp and to the pressure of the felt upon it. By the time the third cylinder or so is reached, the paper is considerably drier and the pressure of the felt no longer seems to have its harmful effect. Indeed, just as the temperature of the drums has to be increased progressively from drum to drum, so, too, has the pressure of the felt to be graduated, although the maximum in the one case is reached long before that of the other.

An illustration of a patented roll for the endless felt bands referred to is shown in Fig. 85. This design is the invention of Bertrams, Limited, of Edinburgh. The body of the roll is a plain steel tube. Each end piece is like a belt pulley with six arms. The rim is split between three of these arms and the boss between the remaining three. The hole in the boss is tapered to receive the tapered end of the gudgeon pin. By screwing up the nut on the pin, the "pulley" is expanded and made to grip the interior of the tube in a secure manner. The construction permits of the tube or the gudgeon pins being readily replaced when necessary.

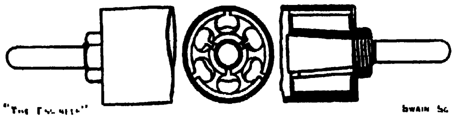


FIG. 85.—Felt Roll - Bertrams'.

CHAPTER XI

PULP STRAINERS

PRACTICALLY the last treatment accorded to the pulp before it is passed on to the wire cloth of the Fourdrinier wet end is, as we have seen, to strain it. To the inexpert eye, pulp, after having been strained, is no different to pulp before straining. Yet, were straining omitted, the difference entailed in the finished paper would be noticeable to most. The object of straining is to hold back all insufficiently pulped particles of fibre and any fine impurities which may escape past the refining engine, sand tables, &c. In spite of all the precautions taken, big pieces of fibre and objectionable impurities are present in the pulp as delivered to the machine-house, and that straining is most necessary if a good uniform quality of paper is desired is obvious to anyone who sees what a strainer holds back.

The importance of straining has led to a great deal of ingenuity being exercised in the design and construction of appliances for the purpose, and it is not out of place for us to devote the whole of this chapter to the description of some typical straining machines. The actual straining is performed in all cases with which we are acquainted by causing the pulp to flow through thin slots, which vary in width according to the quality of the paper which is to be produced, from 0·006 in. to 0·05 in.[1] It may be inferred, therefore, that the average spicules of fibre will pass lengthwise, but not crosswise, through the slits.

The process seems simple enough, but in practice great difficulty arises in coaxing the fibres through the slits and in keeping the slits clean and free from the fibres and dirt that should be held back. Most of the machines in use assist the passage of the proper fibres through the slits by agitating the unstrained pulp. Some vibratory device is therefore more or less essential, and in use this not infrequently means a considerable and unpleasant amount of noise. Efforts have, accordingly, been made to secure the required agitation silently.

The older forms of strainer—many of which are still in use—employ flat plates in which the required number and size of slots are cut. A typical section of such a plate is shown in Fig. 86. The material usually employed is some special quality of acid-resisting bronze. There need be no secret about the manner in which the slots are cut. We have seen the processes employed at two different works. The grooves behind the slots having been milled out, the slots are cut with a small circular saw of the gauge required, and are thereafter carefully gone over with a hand saw of the same gauge to clear out the curved ends left by the circular saw, and with a scraper to remove the burred edges. With time, the

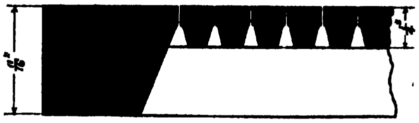


FIG. 86.—Strainer Plate in Section.

---

[1] Three series of gauges—Roger's, Watson's, Bertram's—are in common use, but they are now all the same. The smaller figure quoted is No. 2 gauge, the higher No. 12. The numbers progress by halves—11½, however, is missing—so that there are twenty standard gauges altogether. The corresponding dimensions in inches progress by erratic steps, the origin of the gauges having been quite arbitrary.

slots are bound to wear wider than desired. The makers of the plates do a considerable amount of business in re-closing the slots to the former gauge and in opening others to suit a broader gauge. The closing is done by hand, with a hammer although in some cases we believe it is effected by hydraulic pressure.

The slots are not continuous, but are interrupted, say, every six inches or so, thus leaving solid bars of strengthening metal extending between the sides of the frame. It is the practice of at least one firm —Bertrams, Limited, of Edinburgh—to make these bars run diagonally, as shown in Fig. 87. The pulp cannot, then, pass from one side of the plate to the other without every portion of the flow moving over a slotted area. This style of rib also has the advantage that it enables the plate to be re-closed readily a considerable number of times.

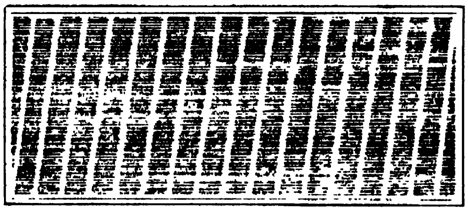


FIG. 87.—Diagonal Rib Strainer Plate.

An example of the older form of strainer employing the flat plates mentioned above is illustrated in Fig. 88. This machine is known as White's patented oscillating strainer, and is made by James Bertram and Son, Limited, of Edinburgh. It consists of a cast iron trough with a false bottom, composed of a convenient number of strainer plates having a total area of 7 ft. by 2 ft. Beneath this the real bottom is formed by a stiff plate united flexibly all round its edges with the walls of the vat. This bottom is coupled to and vibrated rapidly in the vertical direction by a short-throw belt-driven crank shaft mounted on the base of the machine. The vat itself is swung on journals collinear with this crank shaft, and is given a slow oscillating movement about these journals. The drive for this movement is taken from the crank shaft by way of a friction wheel, gearing and an excentric shaft and rod.

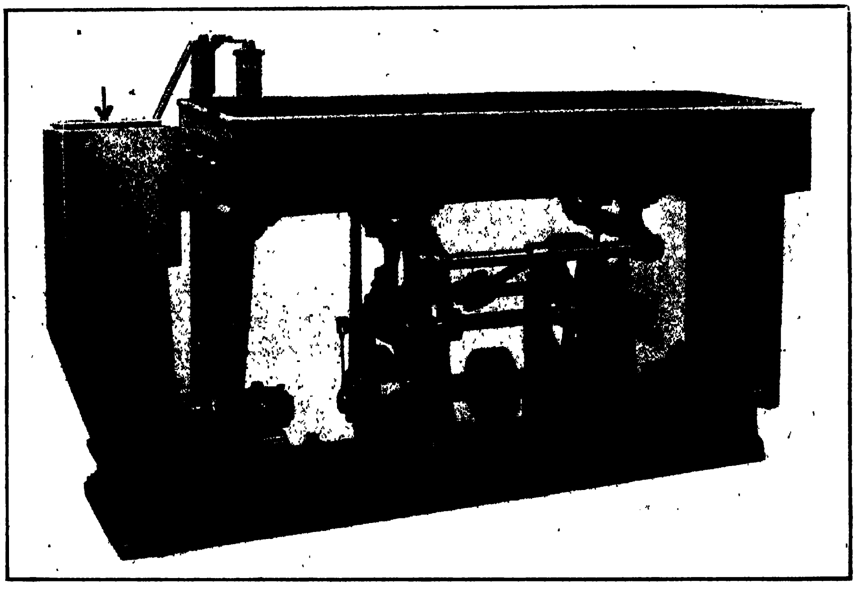


FIG. 88.—White's Oscillating Strainer—James Bertram.

The pulp flows over the top of the strainer plate and is drawn through the slits by the suction action of the vibrating plate below. The clean fibre then flows through a port at one end of the vat into the delivery box shown. The impurities remaining on top of the strainer plate, under the influence of the oscillating motion communicated to the vat and the strainer plate, are swept into side channels whence they are removed through suitable valves. The stuff refused would then be delivered, as already remarked, into an auxiliary strainer. The design of this may be similar to, although smaller than, that of the principal machine. The valves through which the refused matter is discharged are, however, usually hand operated, whereas in the main strainer these valves are ordinarily arranged to act automatically when a predetermined amount of refuse has accumulated in the side channels.

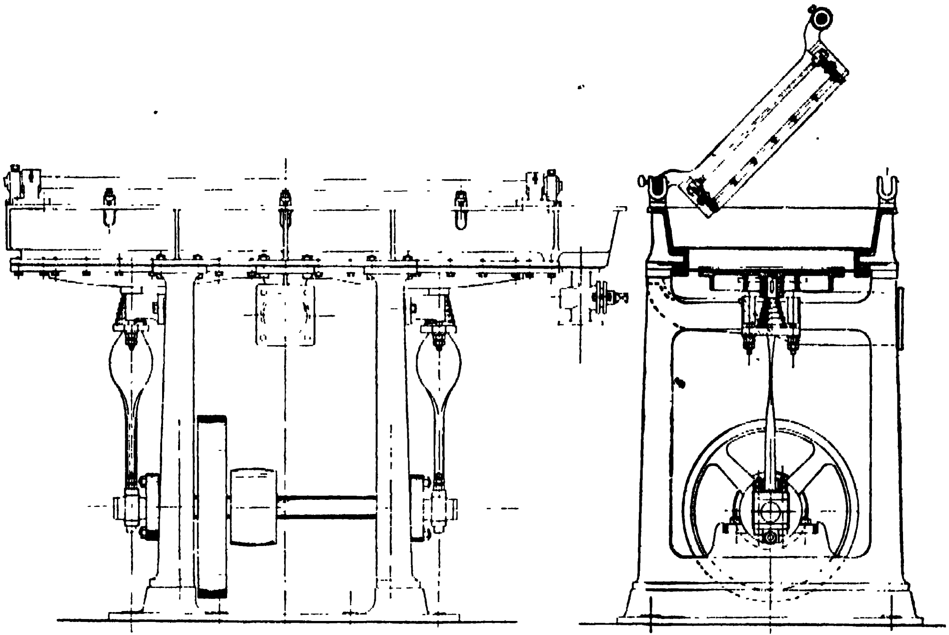


Fig. 89.—Hinged Flat Plate Strainer - Milne.

Another example of a flat plate strainer is illustrated in Fig. 89. The floor of the trough is vibrated through a range of about $\frac{1}{8}$ in. by means of a crank shaft and connecting-rods situated beneath it. The crank shaft runs at about 400 revolutions per minute, and to drive it absorbs about two horse-power. The strainer plates are fixed in a brass frame hinged to the sides of the vat. In the working position this frame beds down on a rubber strip and is held in place by clamps. For cleaning purposes it can readily be swung up into the position shown, so as to permit of the strainer plates being hosed down on both faces. The hinges are "open," so that the frame may be turned up on either side. It will be noticed that the vibrating floor is in two separate portions, one for each crank. The connecting-rod is attached to the centre of the vibrating floor and is guided by two pins sliding within sockets bolted to the main frame. The angularity of the connecting-rod is accommodated by flattening a portion of it sufficiently to make it bend easily through the minute range which is all that is required. This machine is known as Lumsden and Pearce's patented hinged flat bellows strainer, and is made by James Milne and Son, Limited, of Edinburgh.

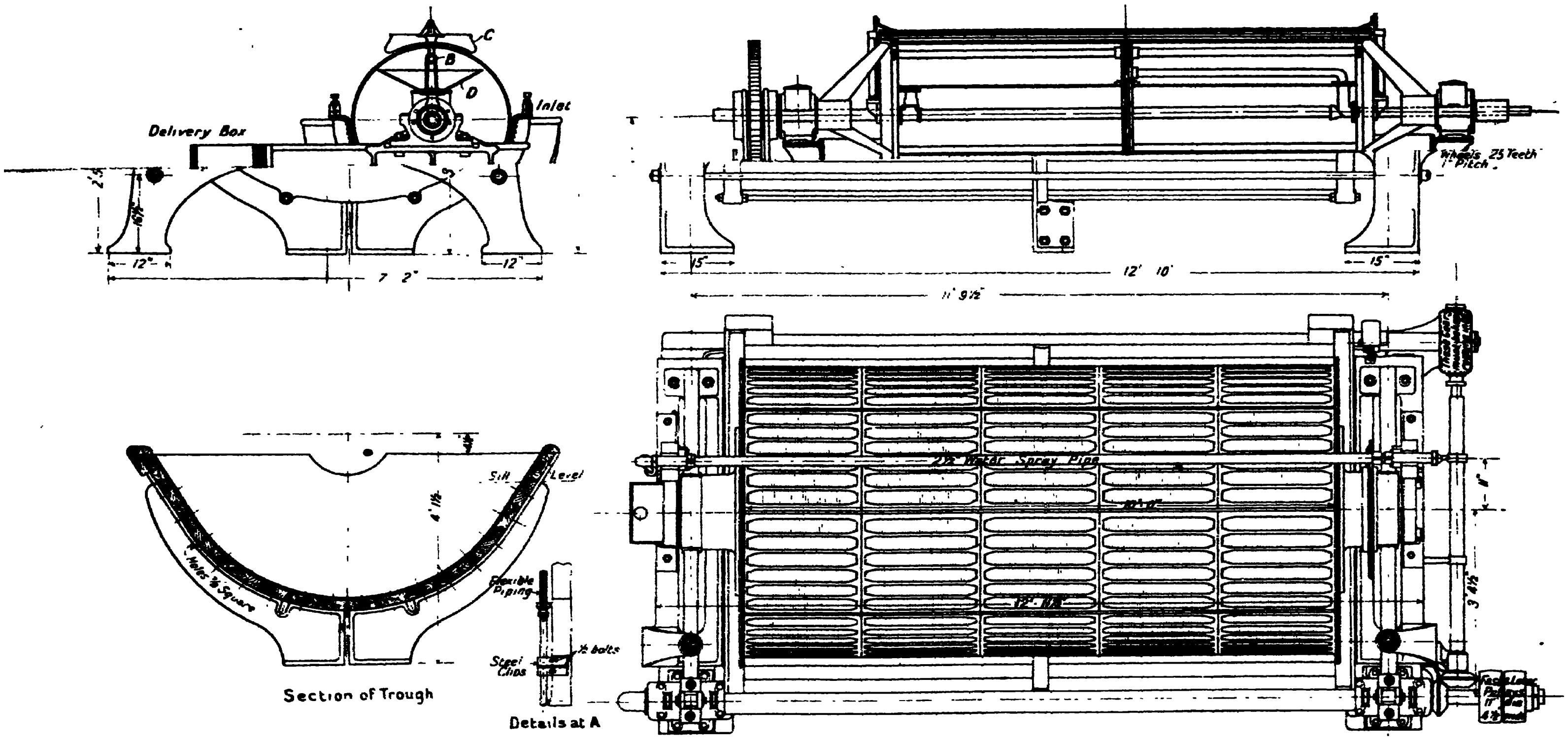
It is generally admitted nowadays that the flat plate strainer suffers from the disadvantage that gravitation acts on the heavy particles and impurities so as to draw them into the slits in the strainer plate. In spite of all that can be done to avoid it, the slits will in time become, partially at least, filled up. Now it is not usual to provide for the storage of the strained pulp between the strainer and the wet end of the machine. The strainer, therefore, must work neither faster nor slower than will provide the right amount of stuff to suit the speed of the Fourdrinier. To avoid a stoppage, therefore, of the whole plant, we must either duplicate the strainer or devise one that will run without choking up for as long as the Fourdrinier is kept going.

These considerations have led to the introduction of the revolving drum strainer, in which the passage of the fibres is usually—but not always—upwards through the slits. With this arrangement gravity assists in keeping the impurities out of the slits. In addition, it is possible to clean the slits continuously while the strainer is in use. An example of this type of strainer is illustrated in Fig. 90. This machine, made by James Bertram and Son, is known as the " Leith Walk " full-drum revolving strainer. It consists of a semi-cylindrical vat of cast iron lined with tiles or copper, and containing a drum, usually made of sheet copper or brass, measuring 7 ft. long by 28 in. in diameter. The straining slits in the drum run in the circumferential direction. At each end of the drum a ring is fixed which sits within a semi-circular rib formed on the vat frame and provided with an india-rubber packing strip. A semi-annular water-tight space is thus formed between the vat and the drum surface, which space is sealed off from the rest of the vat except for the communication afforded by the slits in the drum. Spider arms at each end support the drum from the central driving shaft. The drum is rotated by ratchet mechanism at the rate of about one revolution in seven minutes.

The pulp is fed into the sealed portion of the vat and is induced to pass into the interior of the drum in an inward and upward direction by the influence of a semi-cylindrical vibrating plate shown at A. The strained stuff finds its way from the inside of the drum out through the open ends into a wooden trough or delivery box fixed across the front of the machine. As the drum is slowly revolved, each portion of its surface comes over a series of fine jets of water issuing upwards from a fixed pipe B, situated within and parallel to the axis of the drum. The jets passing through the slits clear out any dirt or fibre which may be inclined to stick in them and carry it to the outside of the drum on to the deflector of a divided trough C, which conducts the water, &c., to waste. Any portions of the jets which miss the slits would fall back into the pulp within the drum and would dilute it unnecessarily. Hence a second trough D is provided beneath the spray pipe to catch this water and carry it off. The bigger proportion of the refused matter collects at the foot of the vat, whence it may be drained off at stated intervals to the auxiliary strainer.

The vibrating plate A is carried on two external arms, being united thereto by pins passing through two flexible discs forming parts of the vat bottom. These arms are mounted on a piston-like member working in a cylinder which is part of a tubular stay stretched between the vat legs. At the centre of the piston member is a short cylindrical piece through which a shaft extends. At one end this shaft is coupled to a small-throw crank shaft. Towards the other end it extends through a second cylindrical piece mounted within a short plunger, the position of which within the tubular stay can be regulated by the hand wheel E. The driving shaft, revolving at

TWO EXAMPLES OF MODERN PULP STRAINERS.



"THE ENGINEER"

Swa. Sc

FIG. 91.—"Partington" Revolving Strainer—Glossop Ironworks.

about 500 revolutions per minute, communicates a like number of vibrations to the piston member, and so to the plate A. The amplitude of these vibrations can be regulated by the wheel E while the machine is running, thereby increasing or decreasing the quantity of pulp being strained. The tubular stay within which the driving mechanism is accommodated is constructed to serve as an oil bath. It is claimed that the strainer runs without noise.

A somewhat similar type of strainer by the same makers and known as the " Leith Walk " half-drum stationary strainer is illustrated in Fig. 96 on page 105. The only essential difference lies in the fact that the drum is replaced by a semi-cylinder, and that it is not rotated by power. The water jet and the associated troughs are suppressed. In use, the strainer plate is turned by the hand gear provided for the purpose little by little at intervals, so as to present fresh portions of the straining surface to the pulp. When it is desired to clean out the slits, the half-drum is turned right up into the position shown in the end view—Fig. 96—and the surface washed.

The drum strainers dealt with above are characterised by the fact that the pulp flows from the outside to the inside of the drum. The reverse method is also in use, and has been for the past twenty-two years or so. An outward-flow or Wandel type strainer made by the Watford Engineering Works, Limited, Watford, Herts., is illustrated in Fig. 97, on page 106. This form of strainer is, we understand, particularly adapted for " news " paper pulp, although it is in use for other classes in which the output required is not more than 4 cwt. to 8 cwt. per hour.

The strainer drum in this machine is provided with partially closed ends and works over a shallow, oblong cast iron trough. The pulp is fed into the interior through a pipe supported in the bracket A. On each drum end a flange is formed, and, as shown in Fig. 92, these flanges rest in cradle arms pivoted at one end to the side of the vat. At the other end the arms carry steel hammer blocks B—Figs. 92 and 97—which cooperate with ratchet pinions on the driving shaft C. A set screw bearing against a rubber-buffered stop on the vat side serves to adjust the drop of the arm. The rotation of the driving shaft by these means vibrates the drum vertically through a range of about ⅛ in. from 600 to 1000 times a minutes.

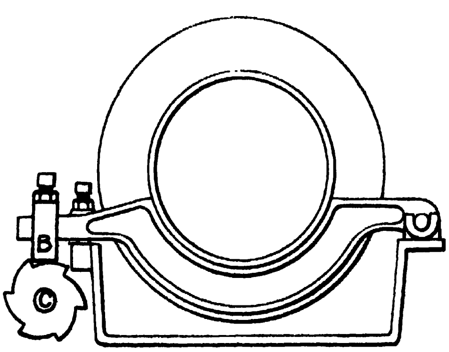


FIG. 92.—Detail of a Wandel Strainer.

Simultaneously, the drum is slowly rotated on its cradle arms by means of a ratchet wheel fixed to one of its ends. This ratchet wheel is driven from the shaft C by the excentric and lever gear shown in Fig. 97. It is claimed that the rotation of the drum by this arrangement greatly assists the passage of the pulp through the slits as the drum is moved round with a series of jerks. Above the drum is a perforated pipe D from which the water is sprayed to clean the impurities, &c., out of the slits. The water, &c., having done its work, falls into the tray E, which conducts it away.

The drum of the strainer illustrated is 7 ft. 1 in. long by 2 ft. 4 in. in diameter, and is made of a hard-rolled acid-resisting bronze. The chief point of interest in this machine is the fact that by the adoption of the outward flow principle the use of india-rubber or other form of sealing rings is avoided. Against this we may put the disadvantage that gravity tends to draw the impurities into the slits. As, however, they are cleared out by the water jets very shortly afterwards, the defect is not nearly of as much consequence as it is in the old flat-plate type of strainer.

Another form of outward-flow machine is the "Partington" revolving strainer made by the Glossop Ironworks Company, Limited. This is illustrated in Figs. 91 and 98. The feature of this strainer lies in the fact that its drum is not composed of a single sheet, but is built up of forty separate plates, each measuring 2 ft. by 2 ft. The drum is 10 ft. long by 16 ft. in circumference. The plates are secured in place by bolting them to stretcher bars which—see Fig. 98—extend between the circular brass end members. Any plate can be readily removed in a few minutes' time should it be damaged or should it be necessary to examine the underside. The effective straining surface aggregates 135 square feet. The plates are made of hard-rolled phosphor bronze.

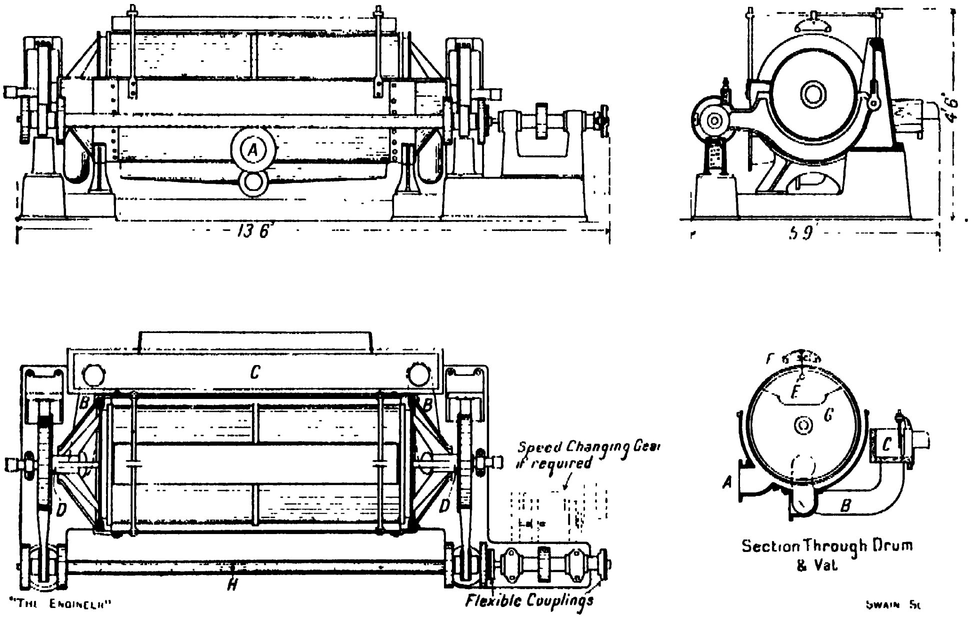


FIG. 93. "Vibromotor" Strainer—Watford Engineering Works.

The ends of the trough are of cast iron, but the semi-cylindrical body or vat is built up of pitch pine staves and is lined with copper if desired. Each end of the drum has bolted to it a circular flanged member, which forms a large diameter hollow trunnion and rests in a saddle provided for the purpose. One of the trunnions carries a sprocket wheel to which power for the rotation of the drum is transmitted by chain from a small back shaft. The cradle beams supporting the trunnions are flexibly bolted to the framing at the rear and towards the front are hung on helical springs. Farther to the front they are provided with pivot pins from which hang rod-like members. These rods, passing through holes in the beam ends, bear against cams formed on the front shaft which extends along the whole length of the machine. By adjusting the strength of the helical springs, the amplitude of the vibration communicated by these means to the drum can be varied. The front and back shafts are coupled up by means of bevel gearing, a cross shaft and worm wheel, the latter gearing running in an oil-tight casing, and serving to reduce the speed.

The cleansing arrangements for the slits comprise an external spray pipe lying slightly to the rear of the top line of the drum. This pipe is closed at one end and is coupled at the other end by a flexible piece of piping to the water supply. Provision is made for traversing this pipe back and forth through a small range, so as to ensure the proper cleansing of the slits. The traversing means consist of a chain drive from the back shaft on to a sprocket wheel, to the spindle of which a cam wheel—actually a plain circular disc mounted askew—is fixed. This wheel co-operates with a roller on the underside of the pipe, contact being assured at all times by the action of a spring plate which tends to push the pipe towards the left. The rejected material and the spray water are caught on an internal tray of copper and brass, and delivered through one of the trunnions in the usual way.

It can be surmised that any arrangement for vibrating the strainer drum which employs a ratchet pinion and hammer, or suchlike device, is apt to prove unpleasantly noisy when in use. A strainer, the driving mechanism of which is claimed to be practically noiseless and at the same time to give a very efficient motion to the drum, is illustrated in Figs. 93 and 99. This is the Vibromotor inward-flow strainer, and is made by the Watford Engineering Works.

The strainer shown in Fig. 99 has a drum 6 ft. 3 in. long by 31 in. in diameter, and is provided with a cast iron vat. The machine illustrated in Fig. 93 is generally similar, but is slightly larger, and has a vat made of sheet copper. The drum ends are formed with gun-metal rings, against each face of which an india-rubber sealing ring is pressed. The pulp is fed into the space between the vat and the drum through the orifice A, Fig. 93, or through the three orifices shown in Fig. 99. The strained pulp from the interior of the drum passes into the usual end chambers, whence it is led by pipes B to a trough C provided with a sluice regulator and from this it flows direct to the wet end of the Fourdrinier. The drum is provided with spider arms at each end which connect it with the short, hollow shafts D. Through one of these shafts a water pipe is led, and is connected with the fixed spray pipe E. The jets from this clean out the slits, and, with the impurities, pass into a special form of overhead trough F. The water which fails to pass through the slits falls back into a trough G, whence it is conducted off through a pipe emerging from the other hollow shaft D.

So far the design follows known lines. The interest of the machine resides entirely in the manner in which the drum is driven. As we have seen, the required motion is twofold, one part being a vibration intended to assist the fibres to pass through the slits, and the other being a slow rotation for the purpose of presenting to the pulp a continuously cleaned straining surface. The driving mechanism adopted is the invention of Mr. W. Worby Beaumont, and has been applied by him to other machines —for example, flour sifters—in which a similar compound motion is required. It is difficult to give a satisfactory account of the kinetics of the drive in the space at our disposal. The following description, based on a personal study of the action, is not intended to satisfy the mathematician.

As will be seen from Fig. 93, a shaft H runs along the front of the machine. This is the driving shaft, and it is coupled flexibly to the source of power. Near each end of the driving shaft there is mounted a disc, or a pair of discs. Each disc carries an eccentric mass adjustable along a radius. These weights are simply a modified form of bolt and nut, and do not weigh much more than ½ lb. each. They normally lie at a radius of about 4 in. to 6 in. from the centre of the driving shaft. They lie at both ends in the same plane and on the same side of the shaft. The entire motion of the drum is dependent upon the centrifugal force developed by these two eccentric weights, and hence the name "Vibromotor," which has been given to this strainer.

The driving shaft is supported in bearings at each end resting on helical springs placed within the pedestals shown at A—Fig. 94. The shaft bearing is formed in the end of an arm B, which is curved downwards cylindrically to receive the lower half of a wheel C, which wheel is united to the hollow shaft of the strainer drum. The arm B is supported at its rear end on a pin D hung from a fixed point of the frame by means of a phosphor-bronze plate spring E. The two wheels C take the whole weight of the strainer drum. They are not in direct contact with the curved surface of the arm B, but rest against a pad of white metal at F, and two smaller pads of "Ferodo" at G. A strap H bolted to the arm B encircles the top half of each wheel C. Contact, however, is only established at J, where an adjustable white-metal block is provided.

The diagram—Fig. 94—indicates all the essential mechanism. It will easily be understood that when the driving shaft is set rotating, the centrifugal force developed by the excentric weight produces a "dithering" or vibrating action. This action may be said with little error to be a rapid swinging up and down of the frame B on the pin D as a pivot. The pivot is not quite stationary, of course, as the spring E permits it to vibrate slightly. It is not at all obvious, however, why, when the driving shaft is rotated at the requisite rate, the wheel C—and with it the strainer drum—should rotate round on the pads F G J. The rate of this rotation, we may say, is adjustable by altering the pressure of the brake block J against the rim of the wheel. We may further add that the wheel C always rotates in one direction no matter in which direction the driving shaft rotates. The rate of rotation of the wheel is directly related to the speed of the driving shaft.

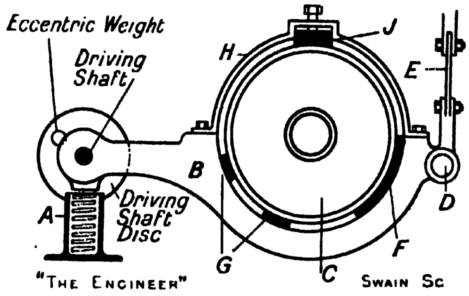


Fig. 94.—Vibromotor Drive.

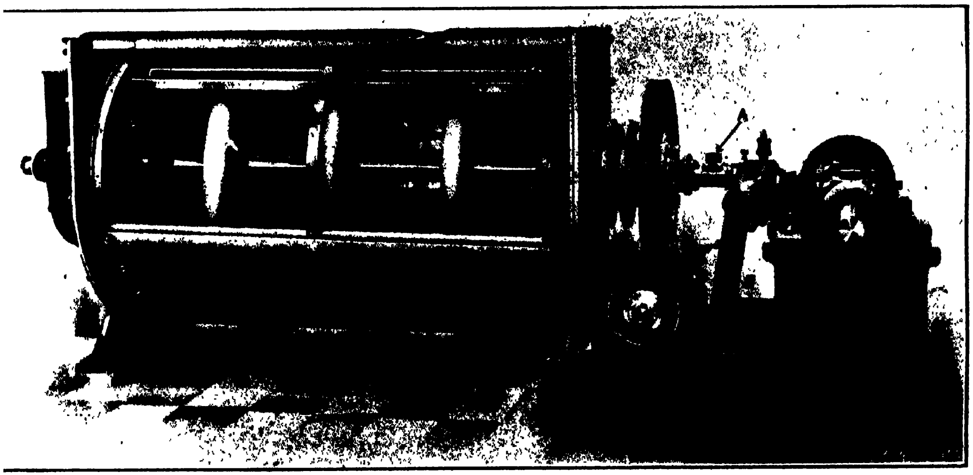


Fig. 95.—"Dickenson" Strainer—Watford Engineering Works.

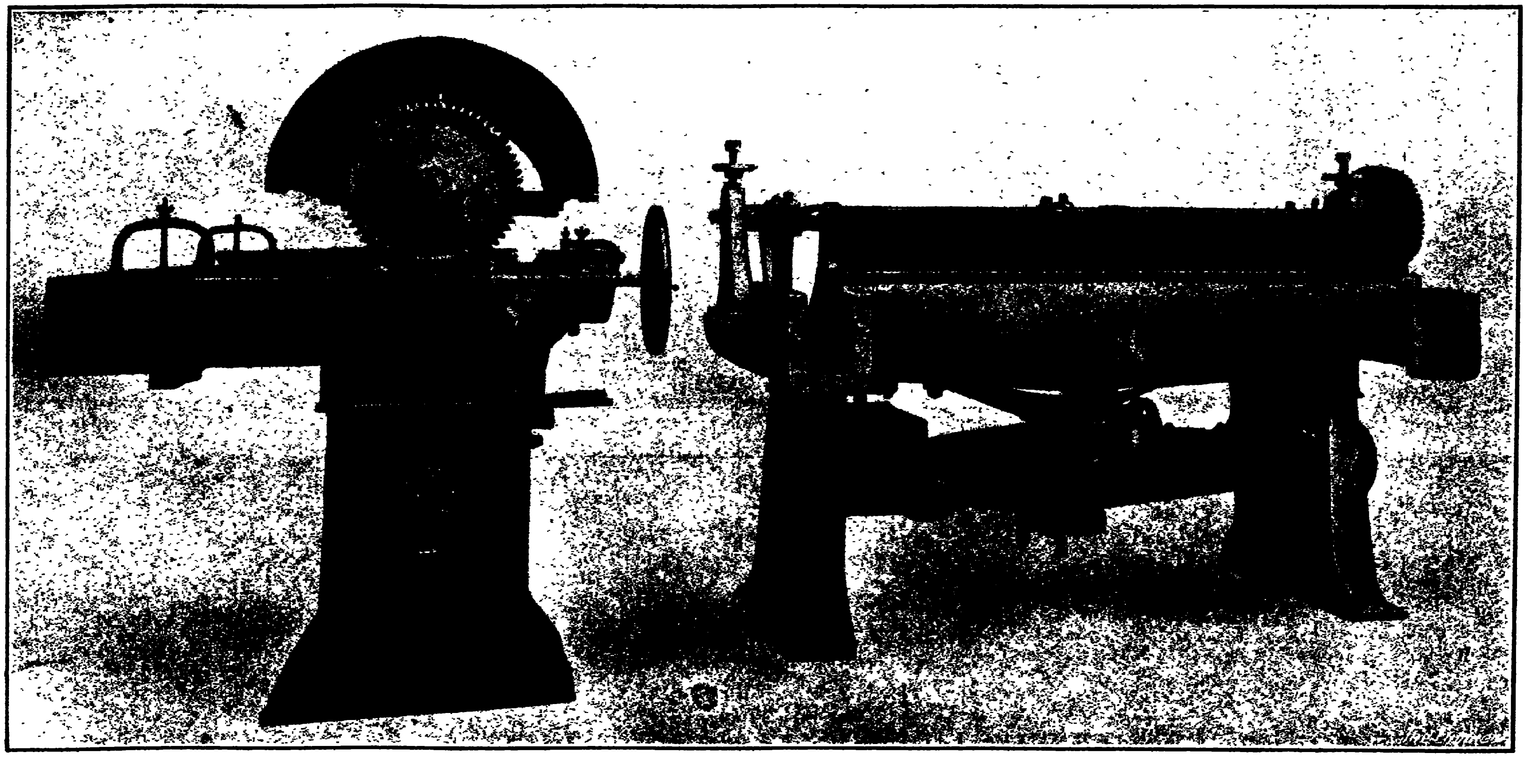


FIG. 96.—"Leith Walk" Half-drum Strainer—James Bertram.

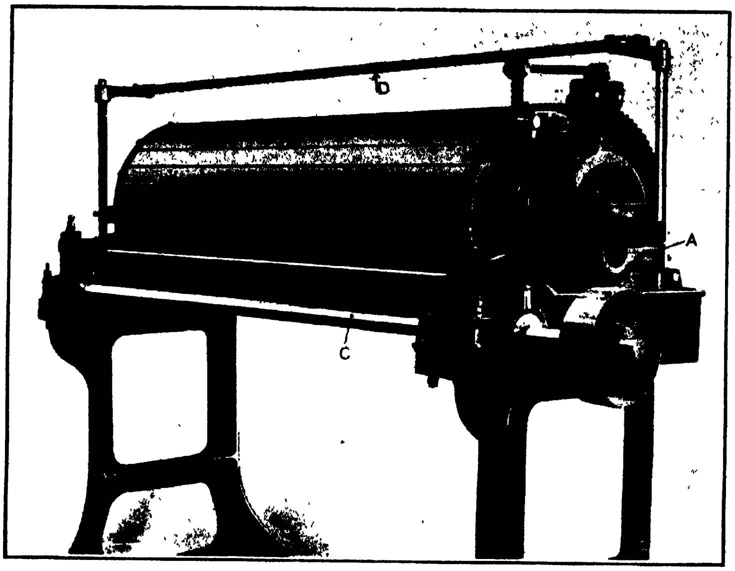


FIG. 97.—"Wandel" Strainer—Watford Engineering Works.

These are the observed facts, and those of our readers who love a mechanical problem will find in them plenty to exercise their talents. For ourselves, we offer the following explanation of why the wheel C rotates when the shaft is rotated, although there is no recognised driving connection between the two. We may say that several illustrations of the same phenomenon are known.

It will be noticed that the pin D at the end of the arm B is constrained by the plate spring E to move in practically a straight, horizontal line. The other end of the frame

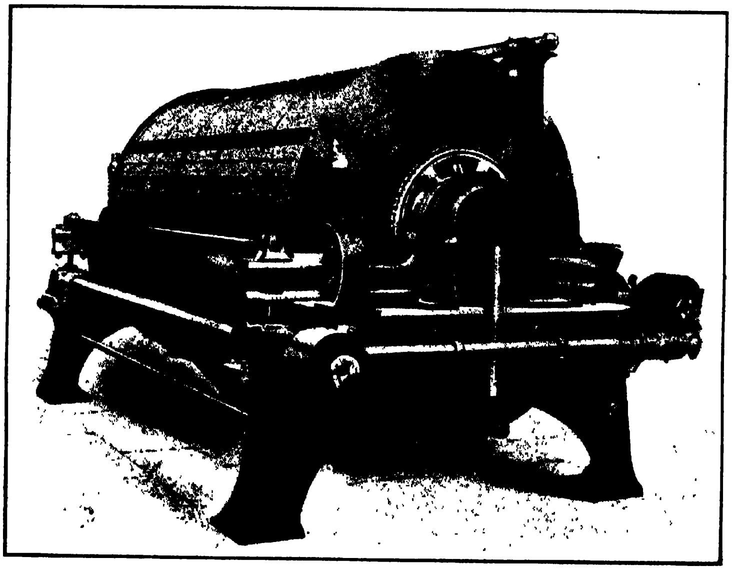


FIG. 98.—"Partington" Strainer—Glossop Ironworks.

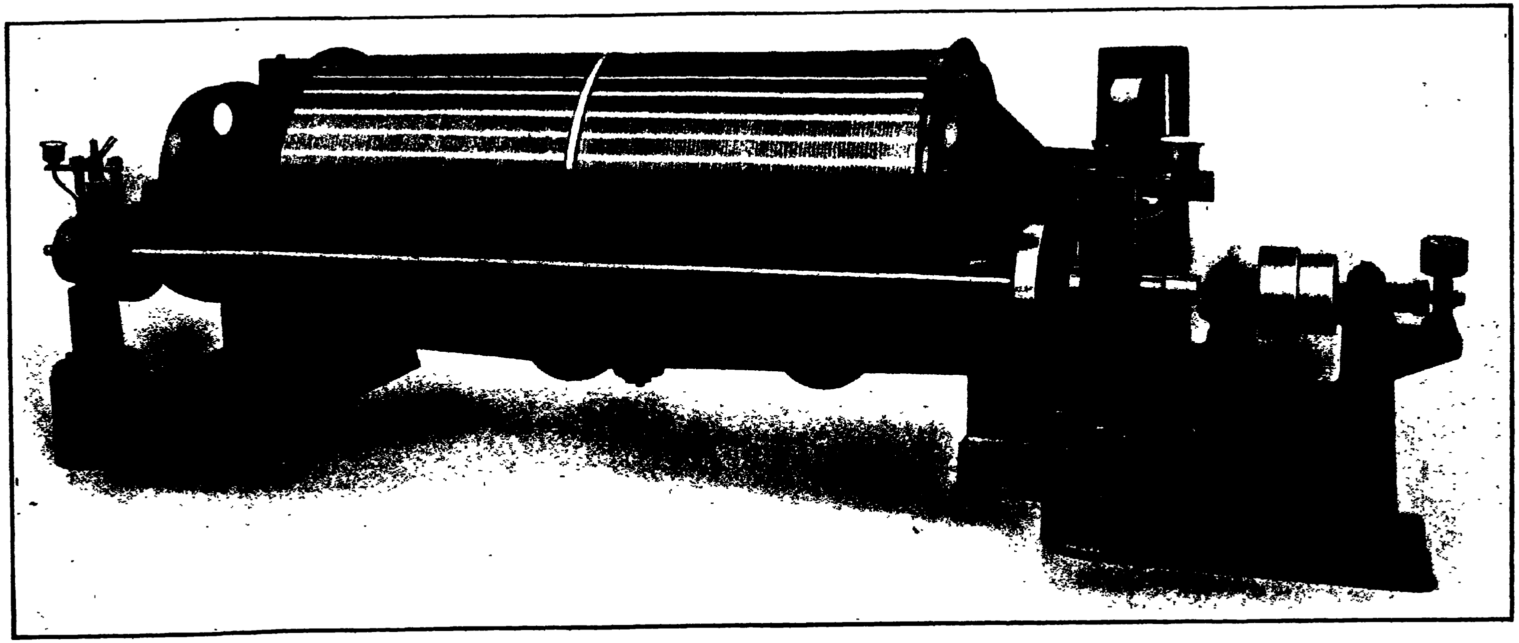


FIG. 99.—"Vibromotor" Strainer—Watford Engineering Works.

is caused to move with the driving shaft in practically a circle. Any other point on the frame, and in particular the centre of the circle enclosing the wheel C, is, therefore, moved in an ellipse. Place a coin inside a ring of a little larger diameter and give the centre of the ring an elliptical—or even circular—motion on a smooth surface. It will be found that the coin will rotate round its own centre in the opposite direction to that in which the centre of the ring is made to describe the ellipse. It is very obviously nothing but a pure rolling motion. It is exactly analogous to pulling the ground from beneath a wheel. If the ground is moved to the left, the wheel moves to the right. In the case in point, it is found that the analogue of the coin may be made as big in diameter as the ring, and may even be braked by the pad J without stopping the rolling motion. We do not advance this as a complete explanation of the drive. Those who desire to investigate it more fully should note that, while white-metal is an "anti-friction" substance, Ferodo is a patented material particularly intended for employment in brake blocks and elsewhere where the generation of friction is a desideratum. It should also be noted that the inertia of the strainer drum provides a resistance analogous to that of the frictional force experienced on the coin face against the flat surface on which it is laid.

This peculiar drive, as we have said, is claimed to produce a very efficient straining motion. In addition, the horse-power absorbed is very small, being of the order of 0·5 horse-power. No ratchet chain or gear wheels are employed, and as a result—even on a temporary foundation, as we saw it—there is scarcely any noise produced. Another feature of the design is the deep immersion of the drum which it permits. In a still later form, the central spiders and the spindle ends have been dispensed with, leaving the drum ends quite open and permitting an even deeper immersion of the drum in the pulp. The Vibromotor drive, we may add, has also been applied to the Wandel type of strainer already described.

A materially different form of strainer from any described above is the "Dickenson" machine, made by the Watford Works, and illustrated in Fig. 95. In this engraving, it will be understood, a portion of the outer casing and a portion of the strainer drum plates have been removed to show the interior arrangements. In this case the strainer drum is almost completely submerged. It is provided with large hollow trunnions, which are passed through glands to the outside of the casing. At one end, one of these trunnions carries a worm wheel, so that the drum may be slowly revolved by a driving shaft through a chain drive.

Passing through the hollow trunnions, which themselves carry suitable glands, is a hollow shaft connected at the worm wheel end to a cross-head and an adjustable throw crank on the driving shaft. Inside the drum this hollow shaft is provided with three equally spaced discs. The rapid reciprocation of these discs draws the pulp into the strainer drum and delivers the strained stuff out through the left-hand trunnion into a suitable delivery box. The gland for the left-hand end of the hollow shaft carrying the discs is fixed on the outside of this delivery box.

The water spray cleansing arrangements are similar to those adopted in the Vibromotor strainer. The overhead trough is shown in section in the engraving. The cleansing water is led into the hollow central shaft by means of a flexible connection attached to the socket A and passes up a vertical pipe to the horizontal spray pipe. The hollow shaft being suitably blocked off, serves at the other end to conduct away the water falling back into the internal tray. It will be noticed that this arrangement incidentally secures the reciprocation with the discs of the spray pipe and the internal tray, as is desirable.

CHAPTER XII

TUB SIZING

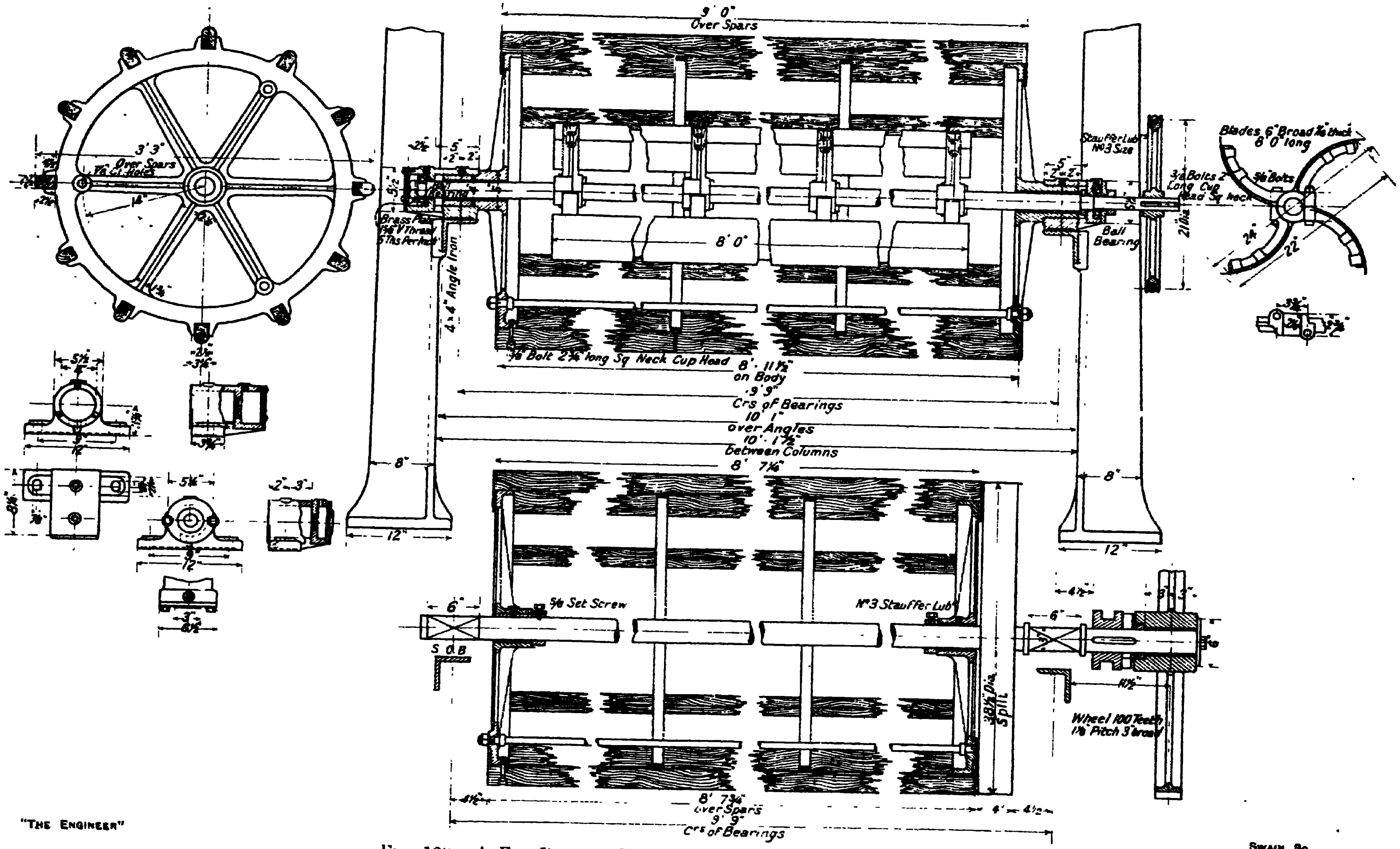
NEARLY all classes of paper, as we indicated in our first chapter, have to be treated with certain substances before they are fit for use. A paper composed of nothing but cellulose fibre would be useless for almost every purpose to which paper is put, and would be particularly so for printing or writing upon. Two kinds of material at least must be incorporated in it. In the first place, the interstices between the fibres must be filled up with some mineral matter, such as calcium sulphate or china clay. Secondly the paper must be sized so as to convert it from something absorbent like blotting paper to something that will not absorb printing or writing ink.

These two sets of materials are very commonly added to the paper when it is in the form of pulp in the beating engine, the action of which incidentally helps to distribute the substances uniformly throughout the mass. On the other hand, while the loading may be added in this manner, the sizing may be deferred until the pulp is converted into dry paper. In this method of working—"tub sizing," as it is called in contradistinction to the other or "engine sizing" process—the dried but uncalendered paper is passed through the sizing solution in the form of separate sheets or continuously from a reel. It is then once again dried when it is ready for calendering.

It is quite obvious which is the easier, cheaper and quicker method of sizing. Engine sizing requires no machinery designed specially for the purpose, and as it is conducted simultaneously with the beating process it absorbs no time. Tub sizing, on the other hand, represents an additional stage in the manufacture of the finished paper, requires separate and special plant and involves a second drying. That it is in use at all is sufficient evidence that it obtains a better result than machine sizing. It may be accepted that tub sizing is resorted to only in the production of certain high-class papers, such as those of the best writing, envelope, account-book and bank-note varieties.

The materials used for sizing paper vary somewhat. For engine sizing they consist generally of rosin dissolved in sodium carbonate. This, with some starch, is mixed with the pulp. A solution of alum is then added, the final result being the precipitation of resinate of alumina among the fibres. The starch acts simply to bind the fibres together, and is not essential to the actual sizing. In tub sizing the paper is passed through a solution of gelatin and alum to which sometimes soap is added.

Engine sizing, as we have said, requires no special machinery. Tub sizing requires little more than an actual tub if the paper is in the form of hand-made sheets. But when it comes to the tub sizing of reels of machine-made paper, additional and special machinery is essential. There have to be provided, in fact, a sizing machine in which the web of paper is drawn continuously through the sizing solution, and then re-reeled, and a drying machine in which the sized paper is gradually dried. Combined with these two machines and following in the order named after the drying machine, it is usual to find a calender, a slitting machine and a re-reeling machine. From the



"THE ENGINEER"

SWAIN Sc.

FIG. 100.—A Fan Drum and a Driving Drum for Air Drying Machine.

slitting machine the paper may alternatively pass to a cutting and laying machine, which cuts the slit web across into sheets and lays these sheets down in a pile.

As an example of the machinery employed in tub sizing, we illustrate in Plate III a sizing and drying machine made by the West End Engine Works Company, of Edinburgh, for Wiggins, Teape and Co., Limited, of Dover. This machine, it is claimed, is the largest of its kind in the world. From the general arrangement it will be gathered that the actual sizing machine, situated at the right-hand end, is a comparatively small affair, and that the great size of the plant is accounted for by the drying machine portion. This portion contains no less than 126 drying drums, during the passage over which the paper is dried slowly by means of hot air. Immediately following come three steam-heated drying cylinders which remove the last trace of moisture from the paper and then two sets of calender rolls. A ripping or slitting machine succeeds the calenders, and from this the slit web can be passed either to a "reel-up" or taken up to a cutting machine and "lay-boy." It will be noticed that a second and smaller sizing machine is incorporated within the drying machine, and that when this is used the web of paper is led over 20 instead of 126 drying drums. Certain papers, bank-note paper for example, are more easily dried than others.[1]

On page 112 a general view of the sizing machine is given, and in Plate IV the arrangement and details of the same part are shown. In the construction of the machine no part coming in contact with the sizing solution can be made of iron or steel. Were such the case the size would attack the metal and cause iron stains to appear on the paper. For this reason the vat in which the paper is sized is of cast iron with a copper lining. Again the dipping rolls, that is to say, the rolls actually within the vat, are built up of yellow pine staves fixed to brass rings carried on brass covered spindles. All the guide rolls are of brass, the squeezing rolls are of a special anti-acid metal, and the reeling-up drums are built of wood.

The vat is 9 ft. square and about 12 in. deep, and is provided with a series of baffles to check the motion of the liquid. It has a false bottom through which hot water is circulated from a steam-heated worm situated in a chamber beneath the vat. By regulating the admission of steam to this chamber the temperature of the sizing solution can be controlled. The reel of paper as received from the Fourdrinier machine is mounted in brackets to the right of the sizing machine. The web is then taken over two guide rolls and down to a small dipping roll within the vat. Passing round this, it is led back to and round a large dipping roll driven by a belt, whence it is conducted, close to the foot of the vat, to the forward small dipping roll. The two small dipping rolls are adjustable vertically and horizontally to permit of the requisite tension in the paper being obtained. From the forward dipping roll the web passes between a pair of power-driven squeezing rolls, which remove the surplus sizing, and then over a guide roll to the reeling-up drum. Associated with each squeezing roll is a "doctor," that is a scraper intended to keep the surface of the squeezing roll in a clean state. The large dipping roll is provided with Skefko ball bearings and the two others with brass roller bearings. The guide rolls also run in ball bearings. The squeezing rolls are carried in ordinary bearings mounted in cast iron brackets bolted to the sides of the vat, and are weighted with two loaded levers.

It might be thought that it would be economical to pass the paper direct from the sizing machine into the drying machine. In practice, however, this would mean starting up the dryer simultaneously with the sizing machine, which would be a trouble-

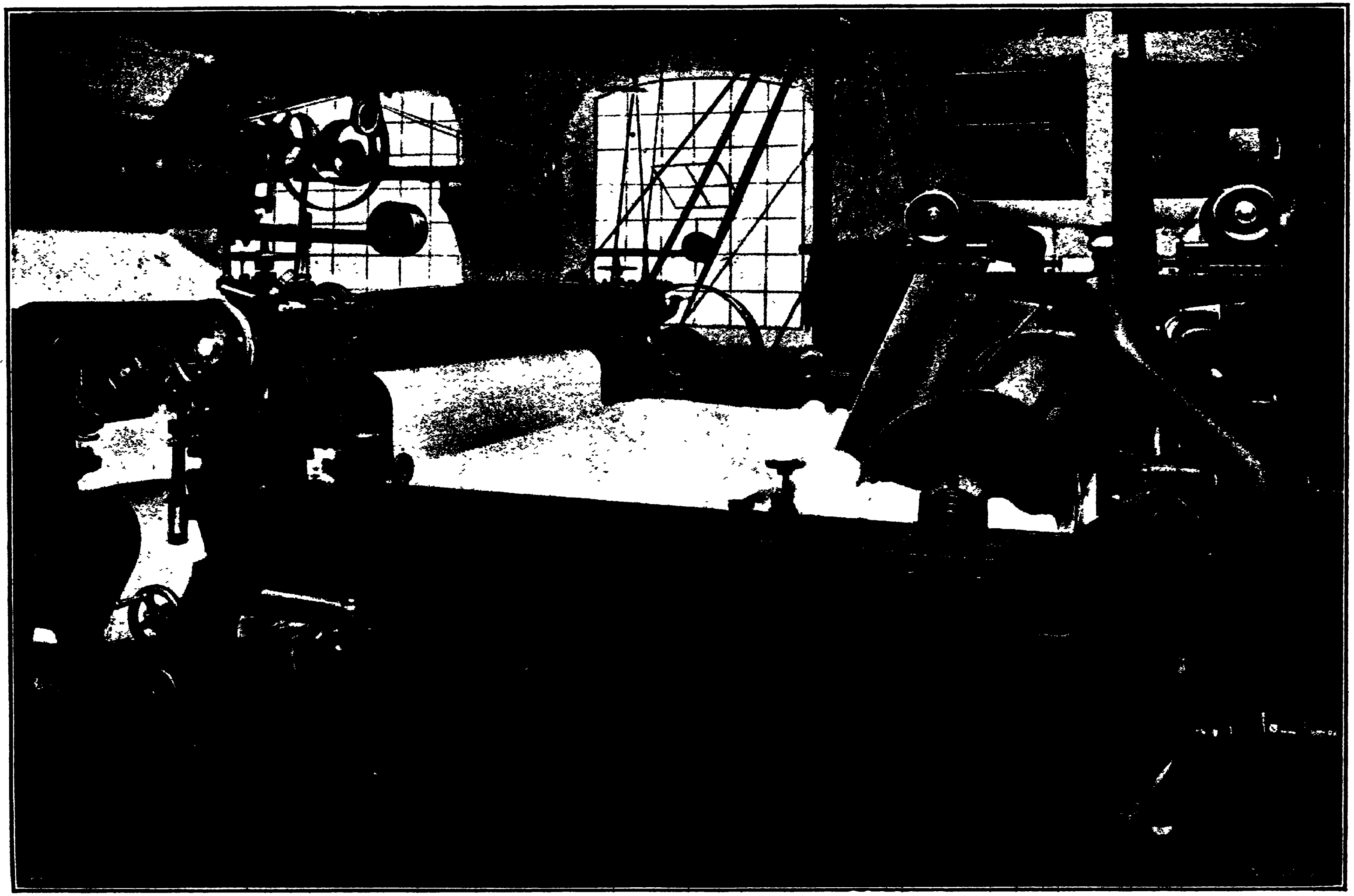
---

[1] The paper known in the trade as "bank" is not exclusively used for the production of bank-notes. It is in considerable demand for other purposes, one example of its use being that among artists for pencil sketching.

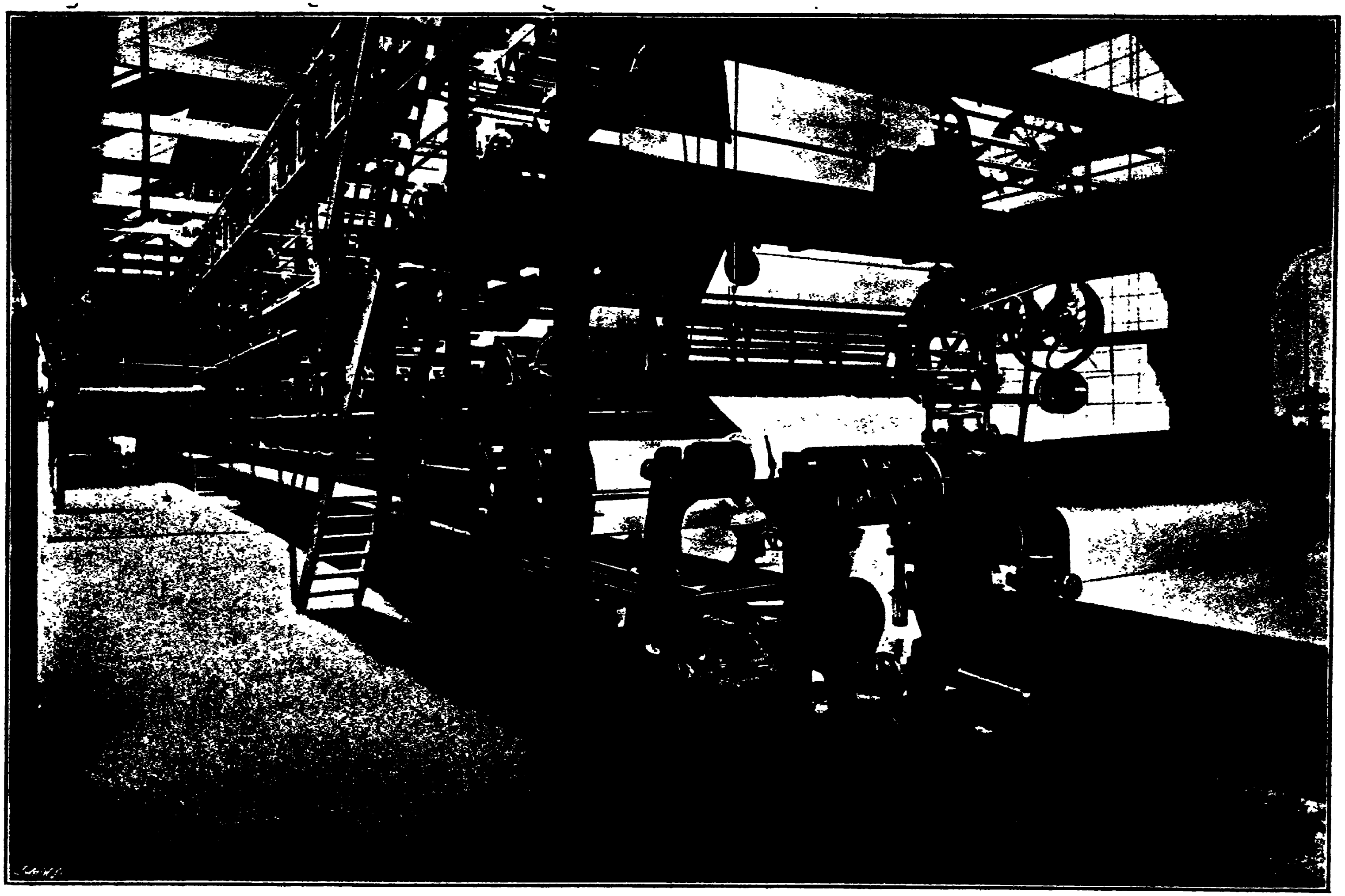
AIR DRYING AND SIZING MACHINE FOR PAPER.

THE WEST END ENGINE WORKS COMPANY, EDINBURGH, ENGINEERS.

(*For description see page* 111.)



The Sizing Machine at Work.



The Air Drying Machine.

some operation in view of the large number of drying drums round which the paper initially has to be led. Again, it is found desirable to allow some time to elapse between the sizing and the drying operation in order that the paper may "soak," that is become properly penetrated by the size. It is for this reason chiefly that the paper is reeled up after sizing and then unreeled afterwards. The reeling-up drum is carried on brackets providing four sets of journals. The paper is reeled up on either the upper or lower drum nearest the sizer, and when the reel reaches a diameter of, say, 3 ft., the web is broken and transferred on to the alternative drum. The sizing machine is thus run continuously. The completed reel is then rolled across to the opposite journals, where it is ready to be unreeled and passed through the drying machine. As the four sets of journals are 3 ft. apart vertically and 3 ft. 3 in. horizontally, four 3 ft. diameter reels could be accommodated on them at one time. In practice one of these reels would be winding on and one winding off. Two of them would be soaking. Actually, we believe, it is not usual to work with more than one reel soaking at a time.

The driving of a sizing machine of this description presents some problems. The points at which power has to be applied are the large dipping roll, the squeezing rolls, and the reeling-up spindle. As the paper is dry before it is passed through the sizer the pull required to rotate the primary winding-off reel is within its strength. The reel is, in fact, braked, and, as shown in the engraving on page 112, the requisite tension is preserved by means of a roller swung on arms and bearing on the top side of the web just in front of the first leading roll.

As shown in Plate IV, power is transmitted to the large dipping roll from a belt pulley fixed on the spindle of the lower squeezing roll. The peripheral speed of these rolls is thus always the same, and they start and stop simultaneously. The lower squeezing roll is directly connected to a shaft carrying a friction clutch and a tapered belt pulley. The driving belt can be moved up the coned surface of the pulley by means of a belt shifter operated by a hand wheel and chain drive from the front of the machine. By means of the friction clutch the rolls can be started gradually without risking the breaking of the paper by a too rapid acceleration of the winding-off reel. By means of the coned pulley the requisite "draw" on the paper can be obtained.

As the paper accumulates on the winding-up barrel its peripheral speed must remain constant to suit the constant speed with which it is passing through the sizing solution. The revolutions of the winding-up drum have, therefore, to be decreased progressively. Each winding-up drum carries a gear wheel, which can mesh with a similar gear wheel on the end of a driving shaft carried in fixed bearings. At the other end of this shaft are a fast and a loose belt pulley. In action the belt touches the top side of the fast pulley, passes round a small jockey pulley and then returns by the underside of the fast pulley. By adjusting the position of the jockey pulley the attendant can alter the tension in the belt, thereby allowing more or less slipping to take place and so vary the speed of the drum as desired.

In either of the reeling-off positions the gear wheel on the drum end meshes with a similar gear wheel journalled on the frame and fixed to a brake drum. This brake is regulated by hand to prevent the reel of paper unwinding too rapidly to suit the speed of the drying machine.

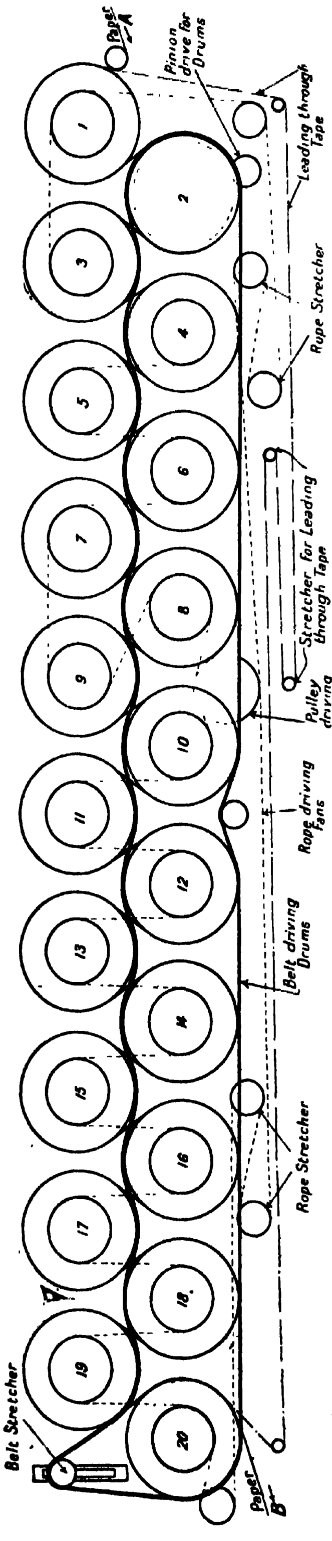
The construction of the small sizing machine is in principle identical with that of the larger. It will be noted, however, that in this case the paper is passed direct from the sizer into the dryer without being reeled up.

The drying machine is, from the engineer's point of view, a piece of plant of great interest. It is not by any means as simple as it looks. When the machine is in full work there is a length of something like 1200 ft. of paper with a width of anything up to 100 in. within it. To start up such a piece of plant as this, involving the leading through it of nearly a quarter of a mile of partially wet paper, is clearly not an easy matter, while to arrange the drive in such a way that no drum shall pull the paper too hard and so break it requires the greatest care. This point covers the same considerations as are met with in the driving of the dry end of a Fourdrinier. As the paper passes through the machine it becomes drier and drier, and contracts accordingly. To avoid breaking the paper, therefore, there must be a certain amount of "give" in the drive. A gear wheel drive would be too inflexible. Hence resort is had to a special arrangement of belt drive, which permits slipping to take place when required. Again the paper must be dried evenly, or it will crease by unequal contraction. For this reason the two sides of the paper have to be dried alternately. How this is effected will be seen by studying in Plate III the manner in which the paper is led over the drums. In each case the side next the drum is that which is being dried by that drum. Another difficulty, at least in this country, lies in the effect which the humidity of the atmosphere has on the drying process. The actual drying is, as we have said, carried out by means of hot air, and on dry days only a moderate supply of such air is required. On wet days the hot air plant may have to work at its maximum rate, while at times even this is not sufficient, and the speed of the machine will have to be reduced to get satisfactory results.

The construction of the drying drums will be gathered from Fig. 100. As shown in the upper elevation, each drum consists of two cast iron wheels held apart by three steel stays and provided with hollow trunnions working in bearings on the main frame. Twelve yellow pine spars are bolted across the wheels, so as to leave a good space between them. Passing through the hollow trunnions is a shaft mounted on ball bearings and carrying within the drum a four-bladed fan made of cast iron arms and steel sheets $\frac{1}{16}$ in. thick. One end of the spars is hooped with a steel plate for the driving belt. The corresponding end of the fan shaft is provided with a grooved rope pulley. Certain of the drums—six in number—are, as shown in the lower elevation, made with an ordinary belt pulley in place of the hoop. They do not contain a fan, but are fixed direct to the central shaft, which at the pulley end carries a sliding dog clutch and a large gear wheel. These six drums are responsible for the driving of the six sections into which the drums are divided.

The drums, then, are driven by belt and the fans by rope. The fans revolve faster than the drums, and draw up the hot air arising from pipes placed beneath the machine and deliver it against the paper.

The manner in which the machine is driven is illustrated in Plate III, which also shows some of the driving details. It is unnecessary for us to follow out the course of all the belts and ropes. In Fig. 101 we show diagrammatically the driving arrangements for one of the six sections into which the whole is divided. In this engraving the larger circles represent the drums and the smaller circles inside them the fans. The paper enters the section at A on the right, and passing round the drums in the order as numbered leaves the section at B on the left. The second drum is of the type shown in the lower part of Fig. 100, and is driven by a pinion. A belt 3½ in. wide passing half round its pulley is carried between the odd and the even numbered drums, lightly touching the hoops on both sets. It is then led round a belt stretcher and returned under the lower drums to the driving pulley. The first drum, it will be noticed, is, no doubt for some good reason, not driven mechanically. The rope driving the fans takes the course indicated by the dotted line, and is driven by a pulley situated



Swain Sc

The Engineer"

Fig. 101.—Diagram of Driving Arrangement for one section of Air Dryer.

between the eighth and tenth drums. Two stretchers are provided for it on the return side.

To facilitate leading the paper through the machine when being started up an endless "leading-through tape"—in reality a fine cotton rope—is provided. This tape, as may just be seen in the general view on page 113, is led over the drums, near one edge, and in Fig. 101 is, for this part of its course, indistinguishable from the line representing the paper. It is shown leaving drum 20 as a chain-dotted line and returning over a stretcher to drum 1. Each of the six sections has one such tape, and as the paper comes through the preceding section the machine tender gives its tail a twist round the tape of the next section. The paper is led from the winding-off reel into the first section in a similar manner.

The driving of the remaining five sections is, in principle, similar to that shown in Fig. 101, and may be traced out on Plate III. All six sections are driven from two main countershafts, one of which is connected up to the six fan driving pulleys and the other to the six drum pinions. Each main countershaft is driven by a high-speed steam engine of 80 horse-power and having a speed variation of 40 to 400 revolutions per minute. This speed range at the engine gives a speed range at the paper of 25 ft. to 250 ft. per minute. Variation of the speed is required not only to meet abnormal weather conditions, but to suit the time required to dry different kinds of paper.

The means for supplying the hot air required by the drying machine consist of steam pipes laid throughout the full length of the bed and taking the exhaust steam of the two driving engines. In addition, there is a special heating plant consisting of a Royle's air heater, also using the engine exhaust, and a belt-driven Sirocco fan. The hot air is conducted into a large pipe situated centrally beneath the drums, and is thence delivered upwards through flap-regulated orifices.

Leaving the last section of the drying machine, the paper passes round three power-driven steam-heated drying cylinders. The construction of these—see Fig. 102—is, in principle, similar to that of the corresponding cylinders in a Fourdrinier machine. Their function is to remove any moisture that may still be left in the paper, and to help flatten the sheet should it be slightly creased from unequal drying.

Two sets of calender rolls follow—also shown in Fig. 102. Next these follow a slitting or ripping machine and a "reel-up." An example of a combined slitting and reeling machine and some calenders by the West End Engine Works Company will be described in our next chapter. As we have already said, the function of the appliances named is to slit the web into, say, three portions and to re-wind each portion separately. The drying cylinders, calenders, slitting machine, and reel-up, as well as the sizing machine at the other end, are all driven by the same engine that is used to drive the drums of the drying machine. In this way any speed variation at the engine affects all parts equally, and does not involve risk of breaking the web at any point.

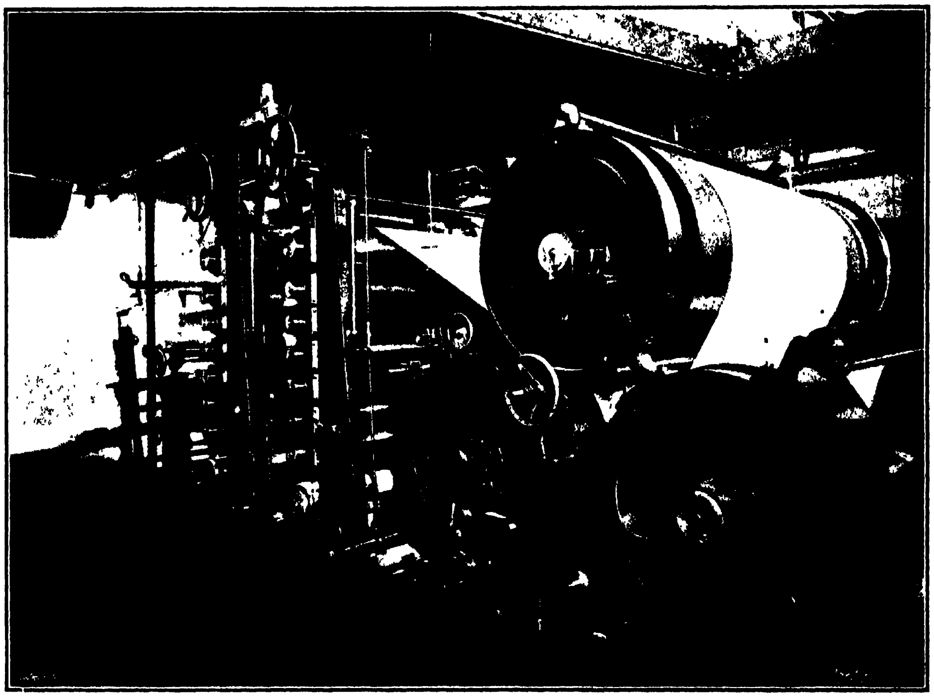


FIG. 102.—Steam Drying Cylinders and Calenders.

As shown in Plate III, the paper, after being slit, instead of being reeled up, can be led directly upstairs to a square cutter, which cuts the material crosswise into sheets. The object of this is to save the time spent on reeling-up and to avoid the necessity of carrying the completed reels upstairs. In practice, however, this method of working is not very satisfactory, and has been abandoned. The paper after slitting is always reeled up and the reels taken as completed to the cutter, which is driven separately from the rest of the plant. The objections to the intended method of working were chiefly two. In the first place the cutter could not be stopped when it was desired to alter the length of the sheets so long as the drying machine was running. Secondly, it involved running the cutter at the same speed as the drying machine, and this speed in many cases was too slow.

CHAPTER XIII

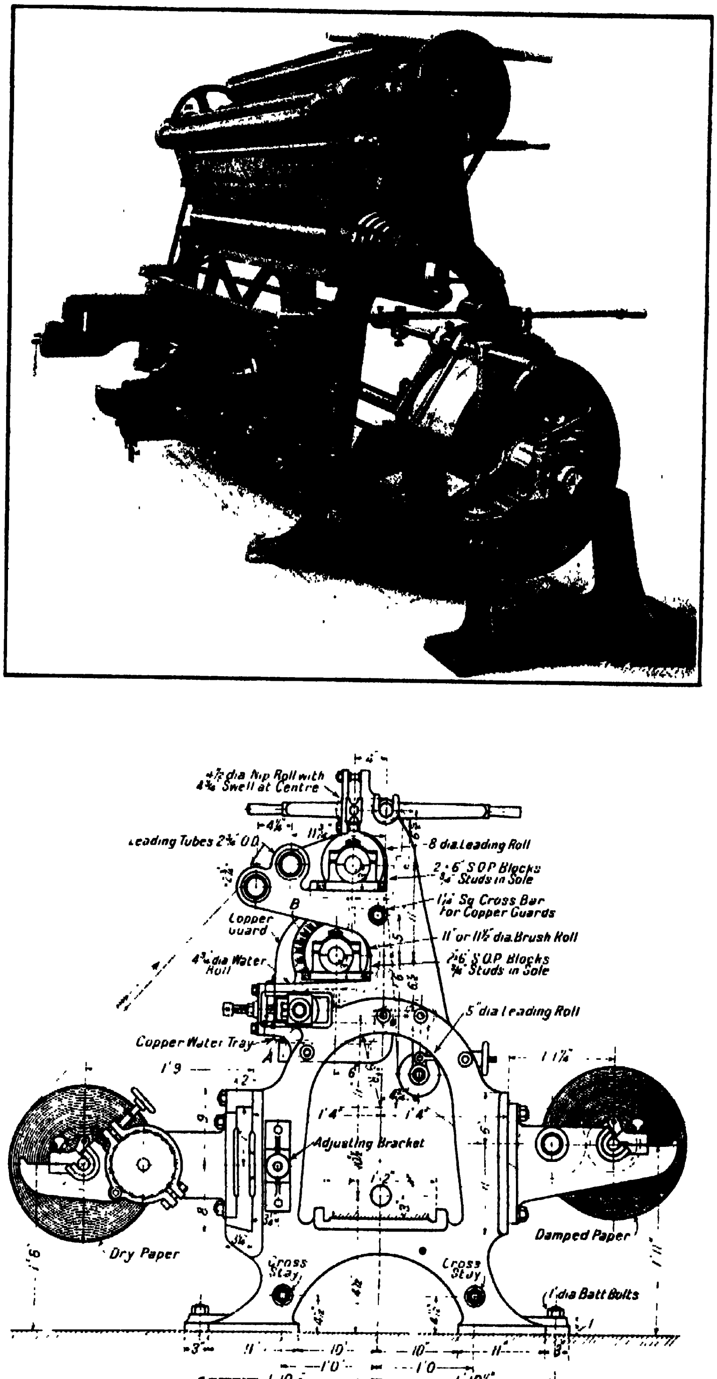
CALENDERING, CUTTING, AND WINDING

THE process of calendering is a most important one. We have before us as we write two samples of paper—a wood pulp paper—which, in our presence, were torn simultaneously, one from the reel of paper as it was going into the calender, the other from the reel as it was being wound up after passing through the calender rolls. It is impossible to indicate the difference by any process of block making, but it is, nevertheless, very striking.

The uncalendered paper has a dull surface, and might readily be taken at first sight for a piece of fine blotting paper. It actually has quite a perceptible amount of "blotting" power. The calendered paper has a shine on its surface, and smudges writing ink. The uncalendered material on one side appears fibrous even to the unaided eye. On the other side it shows the pattern of the wire cloth, on which it was formed, quite distinctly. The calendered material does not show the individual fibres to anything like the same extent, and—a very important point—is almost identical on both sides. It is easy to write with a pencil on the uncalendered paper, but on the other the pencil grips the harder surface with difficulty. Thirty-two pieces of the uncalendered paper have, we find, a total thickness of $\frac{5}{32}$ in., as against $\frac{3}{32}$ in. for the other. The passage of the web through the rolls has, therefore, reduced its thickness by about 40 per cent. We have also roughly examined the strengths of the two papers. The average of eight tests on the uncalendered paper shows a breaking strength of 3·7 lb. per inch width as compared with 4·0 lb. for the calendered.

The degree to which calendering is carried varies with the requirements of the paper user. For many purposes what is known as "machine finished" paper is all that is required, that is, the calendering is confined to the calenders, one or more, at the end of the Fourdrinier machine. When a higher finish is sought super-calenders are used. These are altogether larger and heavier than the calenders already referred to, and are quite separate from the paper-making machine. Where they are in use the paper after passing through the machine calenders is reeled up. The reel is then transported to the super-calender, usually in a different part of the mill, passed through the rolls, and re-reeled. Super-calendering may therefore be regarded as quite a separate process. Machine calendering, if we may so describe it, is part of the papermaking process.

It is found that if the paper is slightly damp before it is passed through the supercalenders the finish on its surface is greatly improved. When the super-calendering is to be carried out soon after the paper is made, the dampening may very conveniently be performed at the end of the Fourdrinier as part of the papermaking process. For this purpose a simple spray pipe delivering a fine mist of water may be fixed crosswise just behind the reel-up spindle. This arrangement seems to serve its purpose very well, although more elaborate devices are frequently employed. In some cases it is not convenient to pass the paper straight off the machine into the supercalender. If this is so the dampening of the paper is carried out immediately before



"THE ENGINEER" SWAIN Sc.

FIGS. 103 and 104.—Rotary Brush Damper—Milne.

the calendering process, and can conveniently be performed in a machine of the type illustrated in Figs. 103 and 104. This machine, made by James Milne and Son, Limited, of Edinburgh, takes in the reel of paper, dampens it, and re-reels it. After a suitable interval for allowing the moisture thoroughly to penetrate the paper the reel is taken over to the super-calenders.

The reel of dry paper is held in journal brackets situated on one side of the main frames and provided with a geared brake for regulating the unwinding of the paper. The web is then led, as shown in the end view, Fig. 104, over two leading tubes to a pair of rolls, the lower of which is driven, and the upper of which is a "nip roll" provided with a hand lever and catch for raising it off the lower when the machine is idle. The web thence passes downwards almost vertically to a hand-adjusted leading roll and so to the power-driven reel-up spindle. During the almost vertical portion of its journey the web is subjected to a fine mist of water delivered by the apparatus to be described immediately. The dampening takes place on one side only, but when the web is re-reeled the dry side is wound on against the wet side, and this fact and the time allowed for soaking secure a uniform penetration of the water.

Opposite the vertical stretch a copper roll A, Fig. 104, is mounted in adjustable bearings, so as to dip into the water contained in a copper tray beneath it. The copper roll can be driven at a variety of speeds by means of a stepped belt cone, and picks up a film of water from the trough. It is an interesting and curious fact that if the roll is driven slowly the film picked up is thin, and as the speed is increased the thickness of the film picked up also increases. The explanation, no doubt, is that the skin friction increases with the speed. The film of water is licked off the copper roll by means of a power-driven bristle brush B, rotating at 1200 revolutions per minute. From the bristles the water is thrown as a fine mist against the web. A copper guard partially surrounds the roll and brush. The copper roll is adjustable away from or towards the brush by being mounted in sliding bearings, as shown in Fig. 104, or in bearings, formed at the end of crank arms, as shown in Fig. 103. This and the speed of the water roll serve as a means of regulating the amount of dampness conveyed to the paper.

The whole machine is driven from the central shaft running at about 220 revolutions. The power absorbed is about 3½ horses, and the speed of the paper something like 350 ft. per minute.

We pass on now to consider the construction and working of calenders. The two machines to be dealt with are both employed after the paper has been reeled at the Fourdrinier. Machine calenders are not in principle different from these, except that they require no reeling-off details, while the reeling-up arrangement is usually separated from them.

A three-roll calender built by the West End Engine Works Company, of Edinburgh, is illustrated on page 122, while in Fig. 105 its general arrangement is shown. Of the three rolls the upper and the lower are of chilled, highly polished cast iron, one or both of which may be steam heated. The intermediate roll is of iron swathed with a covering of raw cotton. All these rolls are of the same diameter—20 in.—and are mounted vertically over one another. The lower roll is driven by silent chain and sprocket wheels from a variable speed electric motor. It is mounted in bearings fixed rigidly to the lower part of the machine framework. The intermediate roll is carried in bearings formed within brackets, which can slide vertically on guides on the machine standard. Its full weight normally rests on the lower roll—or, to be quite precise, on the paper between it and the lower roll—so that when the lower roll is driven by the motor the intermediate roll is rotated in the reverse direction, and the paper is fed through between the pair. The top roll is mounted in a similar manner, and is similarly driven.

Considerable as the weight of the rolls is, it may not, for some purposes, produce sufficient pressure on the paper being calendered. Hence, within the base girders of the frame a lever A, Fig. 105, is mounted on each side. Each lever weighs about a ton, and at its free end carries a series of weights, which may add up to four tons. The levers are coupled by rods to two overhead levers pivoted to the frame. The pull down on these levers is transmitted through vertical rods passing through bearings in the frame on to the journals of the upper roll, and is so transmitted to the others. It is not desirable that this load should be exerted, except when the rolls are rotating, for if they are stationary it will cause two flats to be formed on the cotton of the intermediate roll, which would mark the paper next passed through the machine. Hand levers B, Fig. 105, provided with cam arms, are therefore arranged to be pulled up, and so transfer the loading from the top journals on to the frame base. The weight of the rolls themselves should also be taken off the cotton swathing. For this purpose the thrust rods on the top journals are formed with threaded ends, over which nuts are fitted. These nuts may be rotated down against the frame by hand wheels and so lift the top and intermediate rolls away a short distance from the intermediate and bottom rolls respectively.

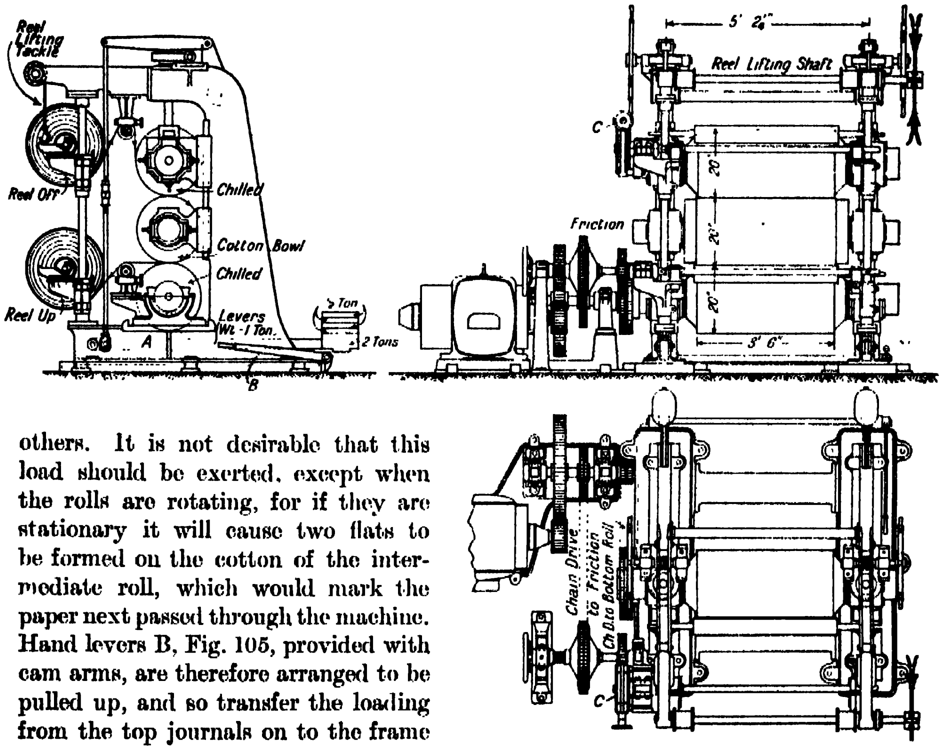


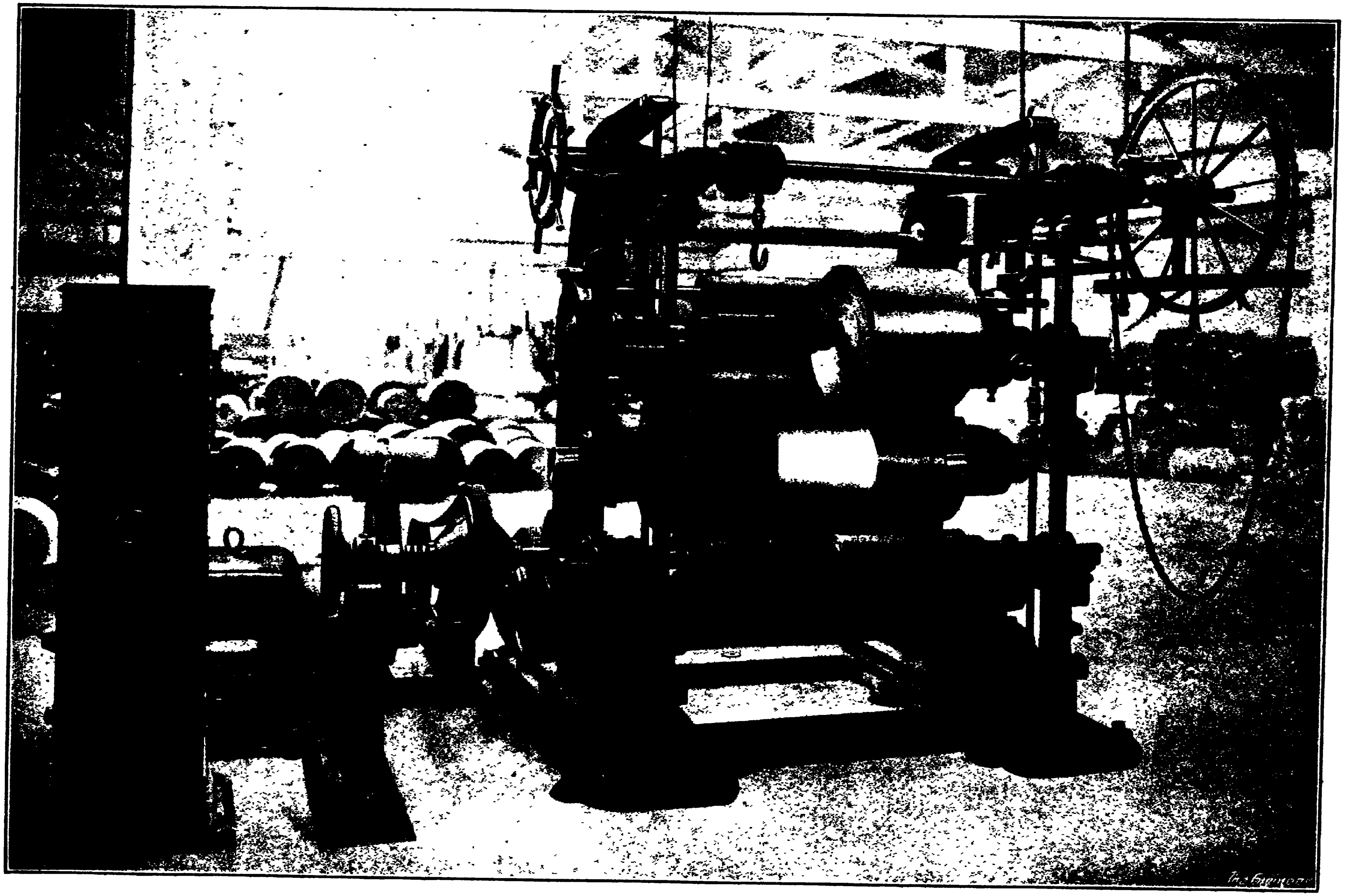
FIG. 105.—42-inch Three-roll Calender—West End Engine Works.

The reel of paper to be calendered is mounted on a spindle, which is lifted up into bearings on the front of the machine by means of a hand-driven chain winch, forming part of the general arrangement. The height of these bearings may be adjusted to suit requirements, for in practice the length of "draw" or "lead" between the reel and the first roll is found to affect the working. The paper is led from the reel first beneath a guide roller, then over and under the top roll, half-way round the intermediate roll, round almost the whole surface of the lower roll, and so over a second

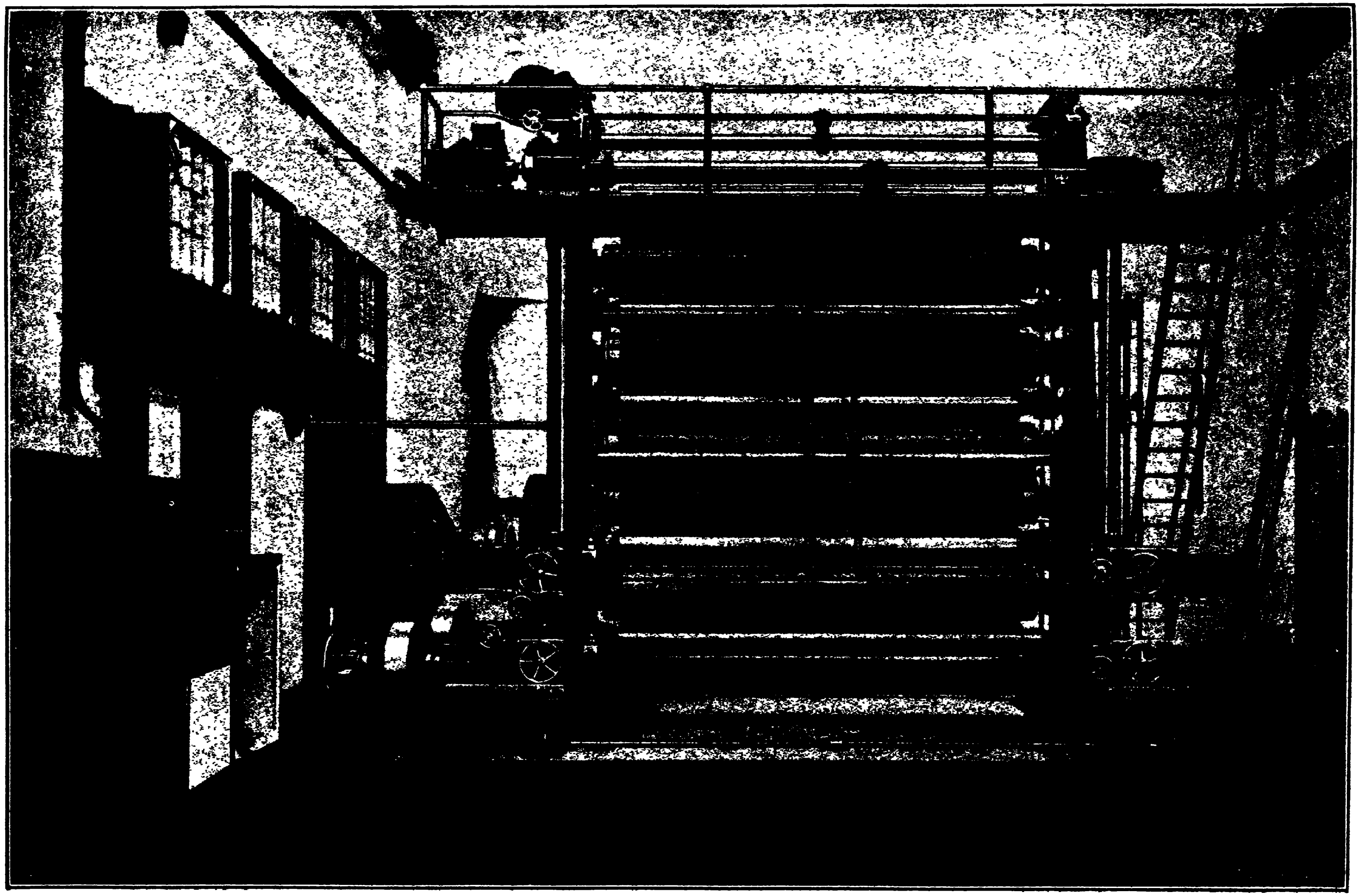
MODERN PAPER CALENDERING MACHINES.

THE WEST END ENGINE WORKS COMPANY, EDINBURGH, ENGINEERS.

For description see pages 120 and 124.)



42-inch Three-roll Calender.



130-inch Ten-roll Super Calender, Electrically Driven.

guide to a second or winding-up reel, mounted directly beneath the first. The actual glazing of the paper, which is one of the objects aimed at in calendering, is produced by the contact of the paper under pressure with the highly polished and sometimes heated cast iron rolls. It will, therefore, be understood that the machine being described glazes the paper on one side only, as is required for so many purposes.

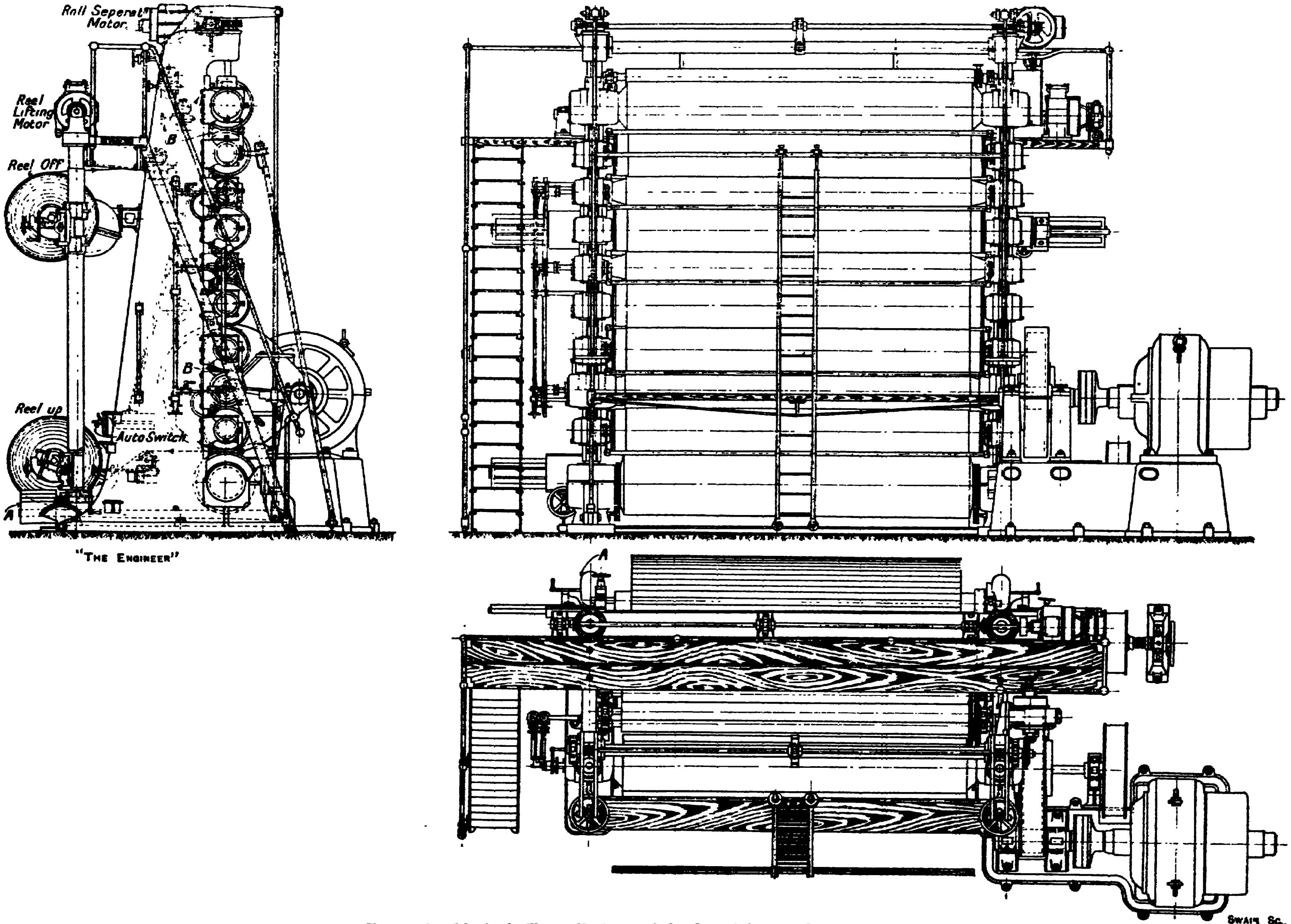
The driving of the winding-off and the winding-on reels presents a problem of some difficulty to solve satisfactorily. Obviously as the upper reel decreases in size, the lower reel increases. The linear speed of the paper through the rolls has to be kept constant from start to finish, for this speed affects the results obtained. It is clear, then, that as the calendering proceeds the revolutions of the upper reel have to be increased, while those of the lower have to be decreased in order to maintain a constant peripheral speed, and thus avoid the tearing of the paper at either reel. This is achieved in the case of the top reel of the machine being dealt with by allowing the pull on the paper itself to drive the reel. A hand brake C, Fig. 105, is fitted to the end of the top reel spindle, and as the calendering proceeds this is progressively eased. It may surprise some to learn that the paper is strong enough to make this possible. The machine in question is specially intended for calendering heavy material. Such material may have a tensile strength in the direction of the pull of as much as 25 lb. or more per inch of width. The roll of paper shown in the view on page 122 is about 16 in. wide, so that its total breaking strength is something like 400 lb.

The lower reel is positively driven by gearing from a countershaft receiving power from the motor through a silent chain. The sprocket wheel on the countershaft is associated with a friction clutch arrangement, which is operated by the attendant to decrease the speed of the lower reel as the calendering proceeds. This detail is illustrated later in this chapter in connection with a machine of a different class, on which it is also to be found..

In Fig. 106 and on page 123 we illustrate a much larger calendering machine—a super-calender—which has been constructed by the same firm of engineers for the *Daily Telegraph* paper mills at Dartford, Kent. This machine has ten rolls, each of which has a working length of 130 in. Five of the rolls are of chilled cast iron and five of iron covered with raw cotton. All the cotton rolls are 18 in. in diameter. Starting at the bottom, the cotton rolls are the second, fourth, fifth, seventh, and ninth. The lowest chilled iron roll is 25 in. in diameter, the third 14 in., the sixth and eighth 12 in., and the top one 20 in.

It will be noticed that the cotton and iron rolls are not alternated throughout, the fourth and fifth both being cotton. Both sides of the paper, therefore, are calendered in this machine. One side receives five passes against a chilled iron surface and the other three. This results, apparently, in a certain inequality of finish on the two sides, although as the two lower iron rolls are of increased diameter the inequality is less than it would be if all five were the same. It will be noticed, too, that the rolls numbered 3, 6, and 8 are steam-heated, so that there is one heated roll for one side of the paper and two for the other. This, of course, tends to increase the apparent inequality of the finish.

The explanation of this departure from symmetry is simply that the paper as it reaches the calender is, by reason of its having been deposited on a wire cloth in the Fourdrinier machine, already "one-sided," and by calendering the side that rested against the wire more than the other, an effort is made to produce a finished material with an equality of surfaces. The reader may examine for himself how very nearly this object is attained in the case of the paper in question. He will equally readily



"THE ENGINEER"

SWAIN SC.

FIG. 106.—130-inch Ten-roll Super Calender—West End Engine Works.

discover instances, frequently intentional, in which there is much disparity in the finish of the two sides.

In the machine being described, the same method—a pile of weights, A, Fig. 106, levers and rods—is used to supplement the weight of the rolls, as in the previous instance. A hand wheel, worm and quadrant, however, replace the hand lever for throwing the load out of action.

The main source of power is a 100 horse-power electric motor. The transmission from this is taken through a flexible coupling and a cast steel Citröen gear pinion to a cast iron Citröen gear wheel mounted on the end of the third roll and running in an oil bath. The speed of the motor can be varied to suit the calendering conditions, and covers a range giving a linear velocity of the paper through the machine of from 40 ft. to 400 ft. per minute. The higher speeds are, perhaps, less seldom required, and special provision, including large electrical resistances, is made for running the machine at long stretches at 40 ft. to 150 ft. per minute. At certain suitable points press-button controls are provided for stopping the motor quickly, a desirable feature in machines of this size, and of much use when the paper is being led through the rolls at the commencement of operations.

As some of the rolls with their brackets weigh as much as 10 tons, it is not surprising to find that electrical is substituted for hand power as a means of separating them at the end of the run, even although the rolls may have to be lifted only once a day, and at times only once a week. For this purpose a small electric motor is fixed on top of one of the standards, and operates, through a shaft and worms, the nuts on the thrust rods transmitting the extra loading on to the top roll bearing. A large threaded shaft, portions of which can be seen at B, Fig. 106, runs from the top roll bearing down behind the others. Adjusting nuts are provided on this shaft beneath each of the eight intermediate roll bearings. There is $\frac{1}{8}$ in. clearance between the bearing of the ninth roll and its nut, $\frac{1}{4}$ in. between the next, $\frac{3}{8}$ in. between the next, and so on. Hence when the top roll is lifted $1\frac{1}{8}$ in. all the rolls are separated by $\frac{1}{8}$ in. The third, or driving, roll has, it will be seen, to rise by $\frac{1}{4}$ in. This is easily accommodated by the driving gear. The pipes of the steam connections to the three heated rolls are bent circularly to provide the required flexibility.

The spindle for the lower, or winding-up, reel of paper is dropped into brackets fixed as regards their vertical position, but slidable in and out to suit varying lengths of spindle. The spindle is driven through gearing from a shaft receiving its power by belt from the main motor and carrying, as in the previously described calender, a friction clutch arrangement for varying the speed as the reel grows in size. The spindle for the upper, or winding-off, reel is dropped into brackets formed on blocks that can be moved up or down on two vertical pillars. The raising or lowering of these blocks is accomplished by means of a third electric motor mounted on the top platform, and driving in unison two screwed shafts passing down in front of the pillars. Automatic switches are provided to prevent the blocks being overwound at either end of their travel. The upper reel spindle is braked as before. The strength of "news" paper is about 10 lb. per inch of width, so that in this machine when running full width well over 1000 lb. is available for driving the upper reel.

It is economical, whether making paper for stock or to fulfil specified orders, to make it in the first instance the full width possible on the Fourdrinier machine possessed, and afterwards to slit it into the required size. The deckle straps on the Fourdrinier are, as we have seen, adjustable to control the width of the paper being made, but this adjustment is intended more for the purpose of making the width of the paper a multiple of the width finally required than as a means of getting the finished width straight away on the machine. The economy of this method of working arises from the fact that it takes practically the same amount of power and the same attendance charges to work the machine at its full width as at any lesser. Even in the case of a paper mill working entirely and constantly on one order as, for instance, a mill owned by a daily newspaper, the practice is to make the paper several times the width of the reels in which it is finally handed over to the printer. As an example, we may quote the case of the mills of a large daily paper, one of the machines at which is capable of turning out paper over 120 in. wide. The paper is, we believe, afterwards slit into three.

In Figs. 107 and 108 we illustrate a machine made by the West End Engine Works Co. for slitting the paper in this manner. This machine is known as a friction winder.

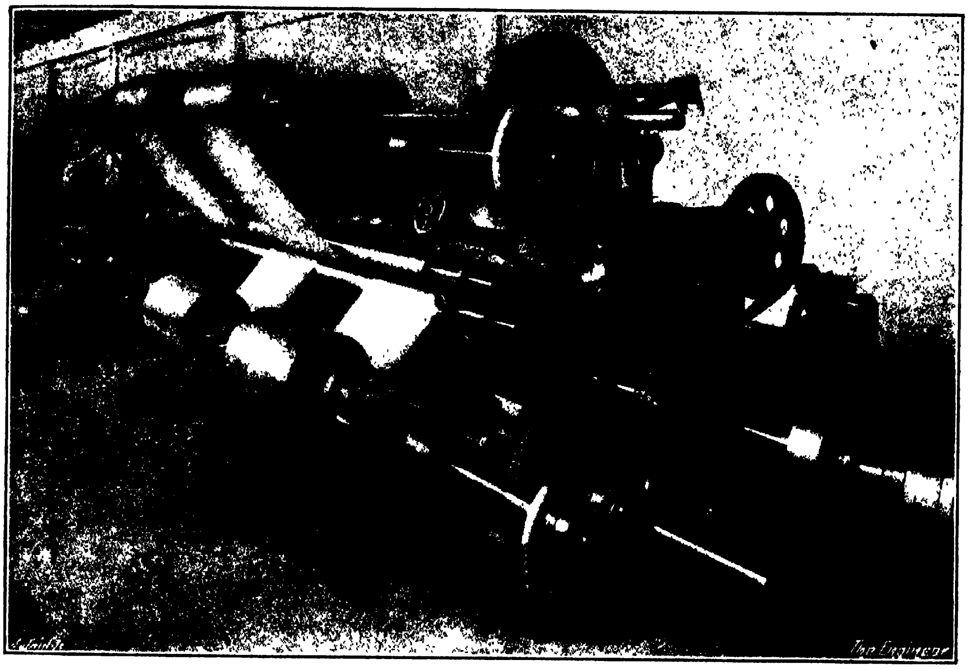
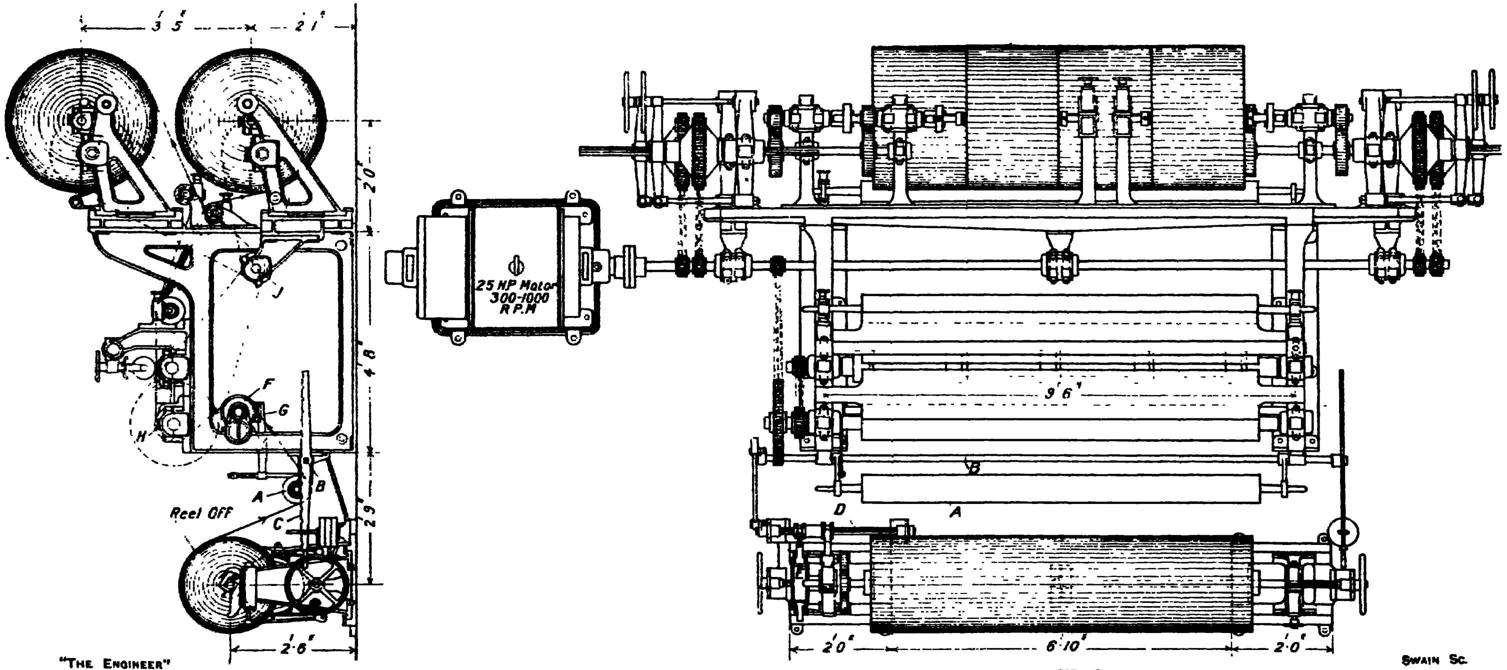


FIG. 107.—90-inch Slitting and Winding Machine.

As shown in our engravings, it is dealing with a reel of paper 92 in. wide, and is slitting and rewinding it into four reels, each 22½ in. wide. It will be noticed that a strip 1 in. or so wide is trimmed off each of the two original edges. The machine can be adapted very readily to perform nothing but this trimming operation on a reel of any size up to 92 in. in width, or it can slit the reel into any number of webs up to four of equal or dissimilar widths.

The original reel is mounted on a spindle, which is supported in brackets that can be adjusted towards or away from one another to suit varying lengths of reels and spindles. This reel, like the top reel of a calendering machine, is not driven mechanically, the pull of the paper being sufficient to rotate it, and is braked in order to maintain the requisite tension in the paper. The braking arrangement is automatic, that is to say, as the reel is reduced in size the braking force is progressively eased to maintain the peripheral speed of the reel constant. This is accomplished by leading the paper



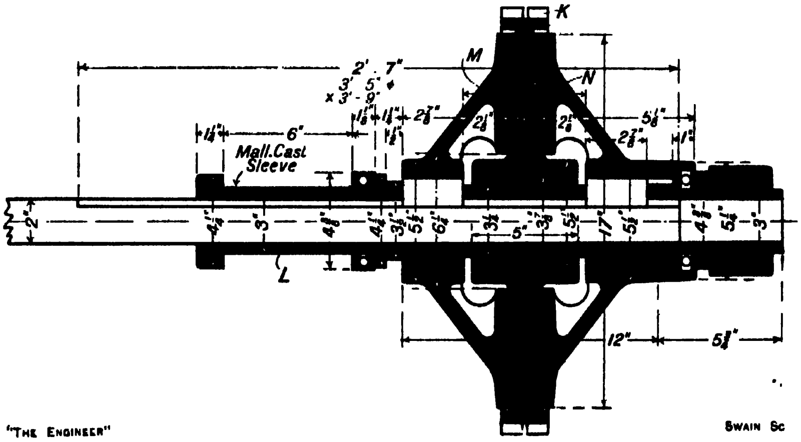
"THE ENGINEER"

SWAIN SC.

FIG. 108.—90-inch Slitting and Winding Machine—West End Engine Works.

round a roller A, Fig. 108, which is mounted on arms extending from a shaft B. At one end this shaft carries a weighted arm C, and at the other is coupled by crank and rod to a shaft D. This shaft carries a sliding sleeve provided with a crank, which is coupled to a brake hanger, the pad of which bears against a brake drum E. The brake drum is driven by gearing from the reel spindle. The drum, the hanger, and the gearing are carried on the spindle pedestal, and partake of its movement when its position has to be adjusted. The sleeve on the shaft D is also connected to the pedestal so as to slide with it. If the reel tends to unwind too fast the lever C will fall and the brake will be applied to check the speed, and *vice versâ*. A second brake hanger on the drum can be controlled by hand from the front of the machine.

From the roller A the paper is led round a roller F, to which a counting device is geared for measuring the number of yards of paper being slit and wound. Should the paper break accidentally, the lever C will, of course, fall. This applies a brake G to the counting roll at once, and prevents a wrong reading of the length being given. The paper is next passed over the power-driven draw roll H, and so to the five sets of circular slitting knives. These knives, with their brackets, may be adjusted along the bed to suit the width of web desired, or one or two may be removed entirely to suit the number of webs.



"THE ENGINEER"

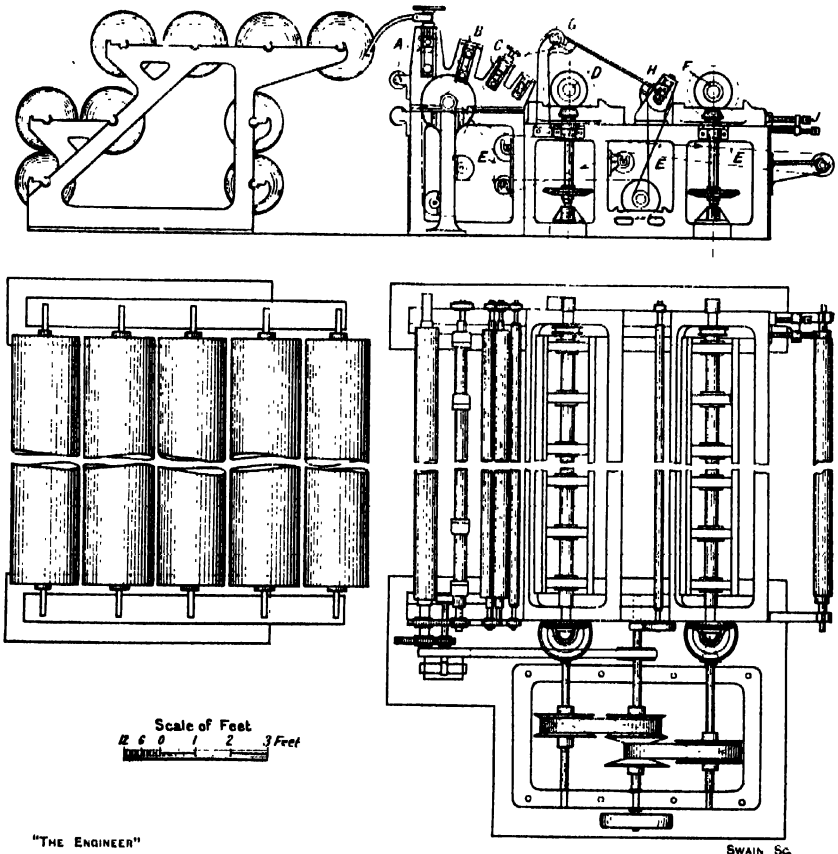
SWAIN Sc

FIG. 109.—Friction Drive Arrangement.

The paper thereafter passes over suitable leading rolls to the winding-up spindles. These spindles are carried on brackets bolted to the front of the machine, and while they are all in the same vertical plane they are alternated as regards height. This arrangement is a feature of the machine. Its strong points are the accessibility it affords to each spindle separately, and the shortness of the spindles which can be employed. There are several other possible arrangements, but they involve either the use of spindles three or four times the width of the reels or the placing of one or more of the spindles horizontally behind the others.

Each winding-up spindle is separately driven by silent chain from the main driving shaft J. As in a calender, arrangements have to be made for decreasing the revolutions of the spindles as the reels grow in size, so as to keep the linear velocity constant. The device employed for this purpose is illustrated in Fig. 109, and is the same in principle as the corresponding device employed on the calenders by the same makers described above. From the main shaft power is transmitted by chain to a sprocket wheel K, mounted freely on a malleable cast iron sleeve L. The wheel K is flanked on each side by a Ferodo friction disc and a conical plate MN. The plate M is fixed to the sleeve, while the plate N is keyed to slide on it. Within the sleeve a shaft slides on a key, and from this shaft the reel spindle is driven by gearing. The action is simple, to screw the plate N against the sprocket wheel, or to ease it, and thus allow the drive to grip or slip by the right amount.

Silent chains are used throughout this machine. The driving power is derived from an electric motor of 25 horse-power, the speed of which can be varied from 300 to 1000 revolutions per minute. The average speed at which the paper is slit and re-wound is 600 ft. per minute.



"THE ENGINEER"

SWAIN SC.

FIG. 110.—Duplex Square Cutter—James Bertram.

For many purposes the papermaker has to deliver his paper not in reels, but in the form of sheets. When such is the case, the machines employed to cut the web are of the nature of those shown in Figs. 110 and 111. Of these, the line engraving represents a duplex cutter made by James Bertram and Son, Limited, while the half-tone engraving is of a small machine made by the West End Engine Works Co. In each case more than one web can be cut at a time. In Fig. 110 the various webs are gathered together between the feeding rolls A, and are thence passed simultaneously between the slitting rolls B. The sub-divided webs thereafter are taken between the feeding rolls C. As they pass over a "dead" knife fixed crosswise on the bed, a revolving knife fixed across discs on the shaft D—plainly shown in Fig. 111—descends at regular intervals and severs the web into sheets. The sheets fall on to an endless travelling felt E, off which they are collected and piled either by hand or by such automatic devices as Vickery's laying machines. It is customary to drive the feeding rolls at a constant rate and to vary the size of sheet cut by changing the speed of the revolving square cutting knife. In both the machines illustrated this speed adjustment is provided for by means of expanding belt pulleys.

The cutter shown in Fig. 110 is of the duplex type, that is to say it is provided with a second revolving cutter at F. After slitting, one or more of the sub-divisions of the webs may be led over the rolls G H to the second cutter, while the others pass under the first. By this arrangement sheets of two different lengths may be cut simultaneously. These machines are run at any speed up to about 180 ft. per minute, and are commonly made to cut sheets ranging in length from, say, 12 in. to 100 in.

It is usual to set the revolving knife across its supporting discs at a slight departure from perfect parallelism with the disc shaft. This is done for the same reason as the moving blade of a shearing machine is set angularly to the fixed blade, namely, in order to shear the work progressively and not all at once, and so reduce the force required. In the present case the displacement of the blade would, in view of the forward movement of the work, result in the cut being made at other than a right angle to the edge of the paper, unless the cutter shaft were, as it is, displaced angularly through a corresponding degree. If the near end of the cutting knife leads, the far end of the cutter shaft must be advanced relatively to the near end. The displacement of the blade on its discs and the forward rate of feed of the paper being constant, the amount of the advancement of the shaft required to give a square cut varies inversely as the speed at which the knife revolves. For each length of paper cut, therefore, there is an appropriate angle of advancement. The adjustment of the angle is effected by means of the set screws J, Fig. 110.

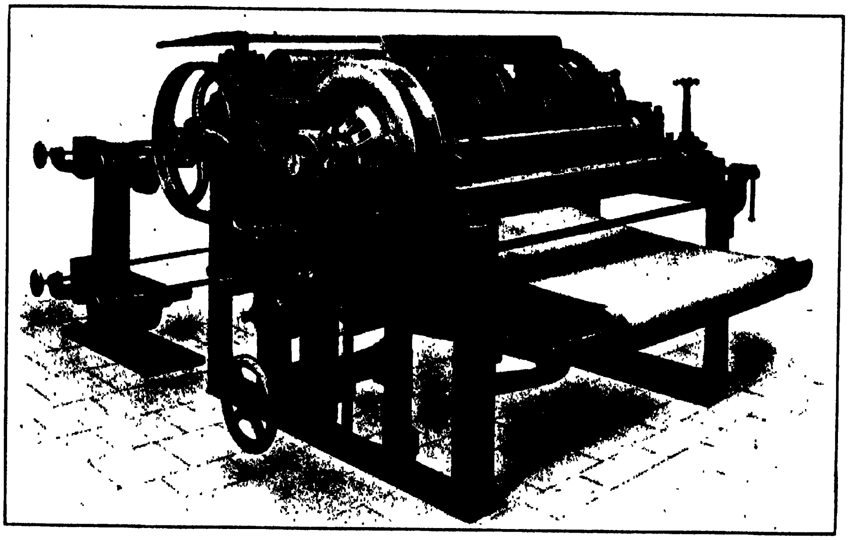


FIG. 111.—Small Square Cutter—West End Engine Works.

This angling of the cutter shaft is not to be confused with what is known as an angle-cutting machine. The latter is, or may be, very similar to the machines described above, with the addition that the cutter shaft is pivoted at one end, while the other bearing is free to be adjusted anywhere on a horizontal arc, so setting the shaft at any angle up to, say, 50 deg. relatively to the cross direction of the web. The sheets are thus not cut square, but at that angle which will involve least waste of material to the user. Such angle-cut sheets are in principal demand by envelope makers. It may also be added here that the adoption of a duplex cutter, such as described above, has a similar purpose in view, namely, the prevention of waste; this time, however, in the mill itself. As we have already said, it is economical to run a Fourdrinier always at or near its full width. This width, let us say, is 100 in. An order may be received for sheets measuring 40 in. square. It would not be usual to set the deckle straps in to 80 in. to fulfil this order, but to make the web the full 100 in. wide in the first instance and then by a duplex cutter slit and cut it into two piles of 40 in. by 40 in. sheets and one pile of 20 in. by 20 in. sheets, or 20 in. by any other standard dimension. If a duplex cutter were not used we would have left on our hands a pile of sheets 20 in. by 40 in., for which there may be no demand.

CHAPTER XIV

WOOD PULP

This book would be regrettably incomplete if we failed to include in it some account of the processes and machinery associated with the production of paper from wood. Introduced into this country about 1870, wood as a paper-making material has come to occupy a most important position. As is well known, practically every one of our daily newspapers are printed upon paper made exclusively from wood. What this means may be gathered from the fact that an important London morning journal selling at a penny uses, on an average, about 50 tons of wood pulp per day. A group of three other London papers uses over 1000 tons a week. Adding some 24 per cent to these figures for loss in manufacture, we find that here alone we have a consumption yearly of paper produced by about 84,000 tons of wood. In a recent year this country imported wood pulp of all kinds amounting to 839,000 tons, and valued at a little over £4,000,000.

It would be a great mistake, however, to suppose that wood pulp is used by the papermaker solely for the production of the cheap and often very poor quality of paper on which the daily newspaper is printed. As a matter of fact, what is known as art paper is sometimes wholly and sometimes in large part composed of wood pulp. From "art" to "news" paper there are many gradations, all of which may contain more or less large quantities of this material.

As we shall explain shortly, there are two classes of wood pulp in use, namely mechanical and chemical. The latter is frequently referred to as sulphite wood pulp, because in its most widely used form sulphurous acid plays an important part in its formation. With this explanation, the table given below showing the composition of certain typical papers should serve to disabuse the reader's mind of any preconceived idea as to the uses to which wood pulp is put. The percentages given in the table relate, it will be understood, to the composition of the fibrous part of the paper. Analysed on a weight basis, this fibrous part might in the case of a high-class art paper be found to represent only about two-thirds of the total constituents, the remaining amount being the loading, sizing, &c., materials. In the case of "news" paper, anything round about 97 per cent of the total might be fibrous, the 3 per cent being loading.

Composition (Fibrous) of Typical Papers

	Esparto per cent.	Sulphite per cent.
Heavy imitation art . . .	80	20
Imitation art	90	10
High-class art	45	55
Antique wove printing . . .	95	5
Esparto printing	80	20
Sulphite printing	—	100
Common art	90	10
Common news	10	90
High-class news	80	20
Cartridge	99	1

It will be seen from this table that sulphite wood pulp is to be regarded as a superior material to esparto grass, while mechanical wood pulp is considerably inferior.

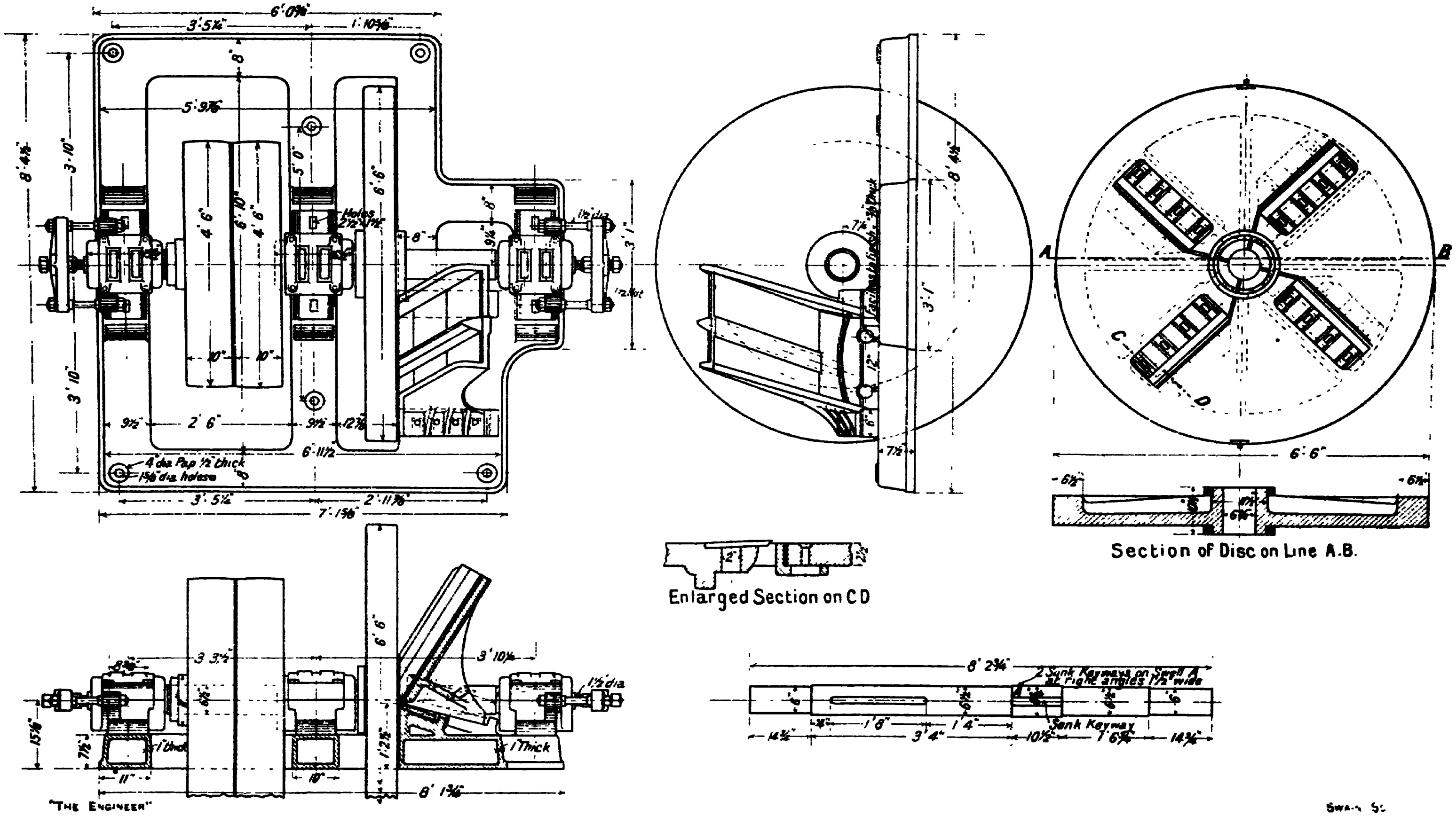
The difference between heavy imitation art paper and esparto printing is considerable, and is due to a corresponding difference in the amount of loading material employed, and the extent to which the calendering is carried. A similar remark applies to the papers called "sulphite printing" and "cartridge."

The woods employed for the production of both kinds of wood pulp are those of cone-bearing trees, such as spruce, fir, pine, &c. The trunks are sawn up into lengths of about 2 ft., and in this condition are deprived of their bark either in a barking machine, which cuts it off by means of revolving knives, or in a "tumbler," a circular drum filled with hot water and acting on the same principle as the "rumbler" used for dressing iron castings. The best pieces, those free from knots, for instance, are set aside for treatment by the chemical process.

Mechanical wood pulp is nothing else than ground-up wood. It may contain not much more than 50 per cent of cellulose, and includes all the resinous matter and other substances, such as lignin, of the original wood. In the presence of these impurities, particularly of the resin, is to be found one cause of the poor quality of paper produced from this pulp. The process employed in its preparation is simply to grind the prepared pieces of wood against a rapidly revolving sandstone. The grinding is carried out in the presence of water, and by varying the amount of the water used and the condition of the surface of the stone two broad qualities of pulp can be produced, hot and cold ground pulp, of which the hot ground stuff is the tougher and stronger. The pulp is screened to remove the coarser material, and is then formed into sheets or slabs by an ingenious machine, closely resembling a Couper concentrator. These sheets or slabs are then pressed hydraulically, when they are ready for export. As they arrive at the mill they contain about 50 per cent. of dry pulp and 50 per cent. of water.

In the case of chemical wood pulp every effort is made to arrive at a substance which is as nearly as possible all cellulose. The removal of the non-fibrous and resinous constituents of the original wood is effected by cutting the prepared and selected logs into chips and digesting these chips with chemicals in much the same manner as is done with all the other raw materials used by the papermaker. In the case of cotton rags, esparto, &c., the digesting chemical nearly always employed is caustic soda. This substance, too, is sometimes used with wood, and gives us what is known as soda wood pulp. But by far the commoner method is to digest the chips in a hot solution of bisulphite of lime under pressure. This gives us the product commonly known as sulphite wood pulp. The bisulphite of lime is usually prepared at the site by burning sulphur or pyrites and causing the sulphur dioxide to unite with lime in the presence of water. After being washed and screened, the raw pulp is worked up into dry sheets on a machine almost identical with a Fourdrinier papermaking machine. These sheets, or slabs, after being cut up to convenient sizes, are ready for export.

It is not possible for us to describe and illustrate the construction of actual examples of several of the machines which, as indicated above, are employed in the conversion of felled tree trunks into sheets of wood pulp. Although there are, we believe, three wood-pulping works in this country, British engineers, it seems, do not lay themselves out to supply the necessary plant. Just as our principal supplies of wood pulp come, or came, from Canada, Scandinavia, and Germany, so, too, do we find the engineers of these countries chiefly responsible for the manufacture of the machines and appliances used in the industry. This is particularly true in the case of mechanical wood pulp, and beyond the references made above, we are unable to illustrate from the practice of British engineers the construction and working of barking machines, tumblers,



"The Engineer"

Swain Sc

Fig. 112.—Wood-chopping Machine—Glossop Ironworks.

wood-grinding machines, centrifugal screens, and the sheet-forming concentrators or wet pressing machines, as they are called. With regard to the plant employed in the production of chemical wood pulp, we are in rather a better position.

Under this process, as we have said, the best pieces of the sawn-up trunks, after having been deprived of the bark, are reduced to chips preparatory to being digested. A wood-chopping machine for this purpose made by the Glossop Ironworks Company, Limited, is illustrated in Figs. 112 and 113. It consists of a heavy cast iron disc keyed to a stout shaft, which runs at a speed of 150 revolutions per minute. The shaft is provided with means for its endwise adjustment, and runs in self-oiling phosphor-bronze bearings. Four steel knives are inserted in the face of the disc, and these can be adjusted so as to project by the most suitable amount from the face. A cast iron feeder box, or shoot, is bolted to the bed to one side of the shaft, and is arranged to present the logs of wood to the knives at such angles, vertical and horizontal, as have from experience been found to result in the least amount of shock when the knives strike the log. The shoot is lined with steel plates, which can be readily removed should their replacement be necessary.

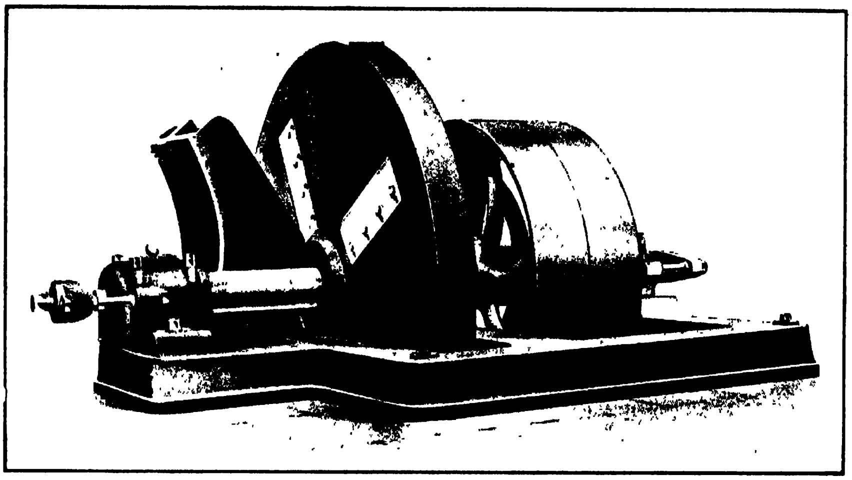


FIG. 113.—Wood-chopping Machine.

The disc is enclosed during working within a sheet iron casing, from which the chips are discharged into an elevator, or on to a conveyor by the centrifugal force imparted to them by the revolving disc. Two small projections, or "bangers," are let into the periphery of the disc. These serve to clear out the chips which fall into the space in the bed beneath the disc. No definite information is available regarding the power consumption of this machine. A constructional feature of it is worth noting. The slots for the knives, it will be seen, are continued down to and through the boss of the disc, and the boss is hooped with a pair of shrunk-on rings. This construction is adopted with a view to minimising the unknown internal stresses produced in the neighbourhood of the boss by the contraction of the metal after casting.

The flakes, or chips, of wood thus produced may, if it is thought necessary, be passed through a sifter, which separates the smaller pieces from the larger. Such a sifter usually consists of an inclined revolving drum having open ends, and with its cylindrical surface formed of fine wire netting supported on a framework. The smaller pieces of wood pass through the netting. The larger travel to the lower end of the drum, whence they are discharged. It is thus possible to deliver to the digester pieces of wood all, in each charge, of much the same size. The object in view has its parallel in the domestic kitchen. A good cook, when boiling potatoes, selects each batch as nearly as possible of the same size individually.

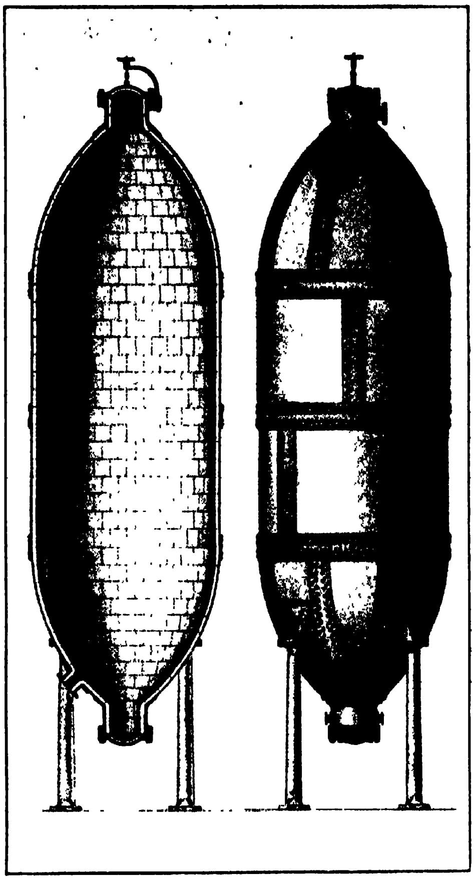


FIG. 114.—Stationary Digester—Bertrams'.

Two forms of chemical pulp digesters, as supplied by Bertrams, Limited, are illustrated in Figs. 114 and 115. In one form the vessel is arranged vertically on fixed pedestals. In the other it is horizontal and can be rotated by power exactly like an ordinary cylindrical rag boiler. The digester is sometimes made spherical in shape. As an indication of the size, we may say that the vertical type may be 40 ft. or 50 ft. in height by 12 ft. to 15 ft. in diameter. In either form illustrated, the digester consists of little else than a strongly riveted steel shell with suitable inlets and outlets for the steam and the pulp. The chief technical interest lies in the lining. If the soda process is in use, no lining need be used, for caustic soda in the strength employed has no action on steel. But if the sulphite process is adopted the steel has to be protected from the corrosive action of the acid-like bisulphite of lime or other salts of sulphurous acid. The lining commonly adopted consists of bricks, or tiles, held in place by cement or lead. The digesters illustrated are, however, provided with what is known as Preston's patented lining, for which, we understand, certain advantages are claimed. This lining consists of tiles embedded in a peculiar paste or plastic material, consisting of asbestos and a solution of silicate of soda, or silicate of potash, or a mixture of the two. Silicate of soda alone seems to be the preferable form. This paste is used not only for holding the tiles to the sides of the digester, but for "pointing" them and for making joints.

The largest size of upright digester may hold as much as 20 tons of wood chips at one charge. The digesting process may be conducted at a pressure of about 80 lb. per square inch, and lasts for eight hours or so. This applies to sulphite pulp. For soda pulp the conditions are similar, except that usually the revolving type of boiler is used. In both instances the condensed heating steam accumulates in the digester and mixes freely with the pulp. Another form of working avoids this by circulating the steam through coils of lead pipe. The pressure inside the digester in this case is kept low, say round about 15 lb., and the digesting process is maintained for a proportionately longer time, averaging about forty hours. The result of this "slow cook" process is a sulphite pulp differing considerably from that produced by the "quick cook" process. It may be here mentioned that many modifications such as this are possible, and are in use. As illustrating this point, we may refer to the production of "kraft" paper, that is a certain quality of very strong and remarkably tough paper having a yellow colour and used chiefly for wrapping purposes and the manufacture of bags. This paper is produced by incompletely digesting the wood in old soda lye, and by completing the disintegration mechanically with an edge runner or "kollergang," such as we described in a preceding chapter.

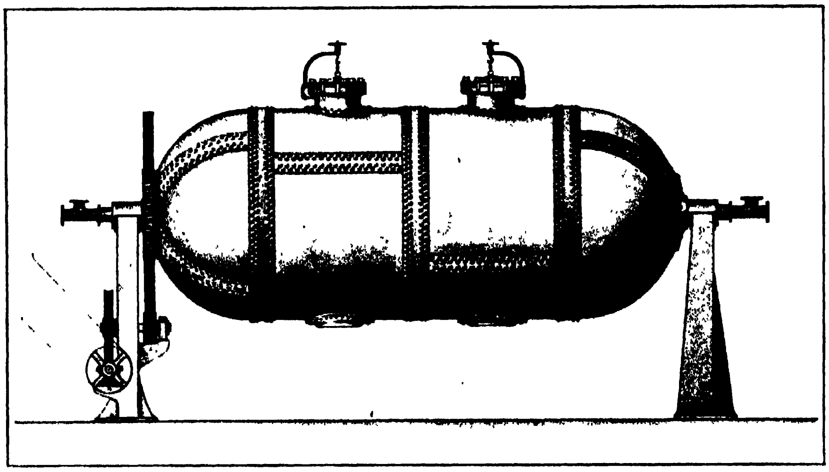
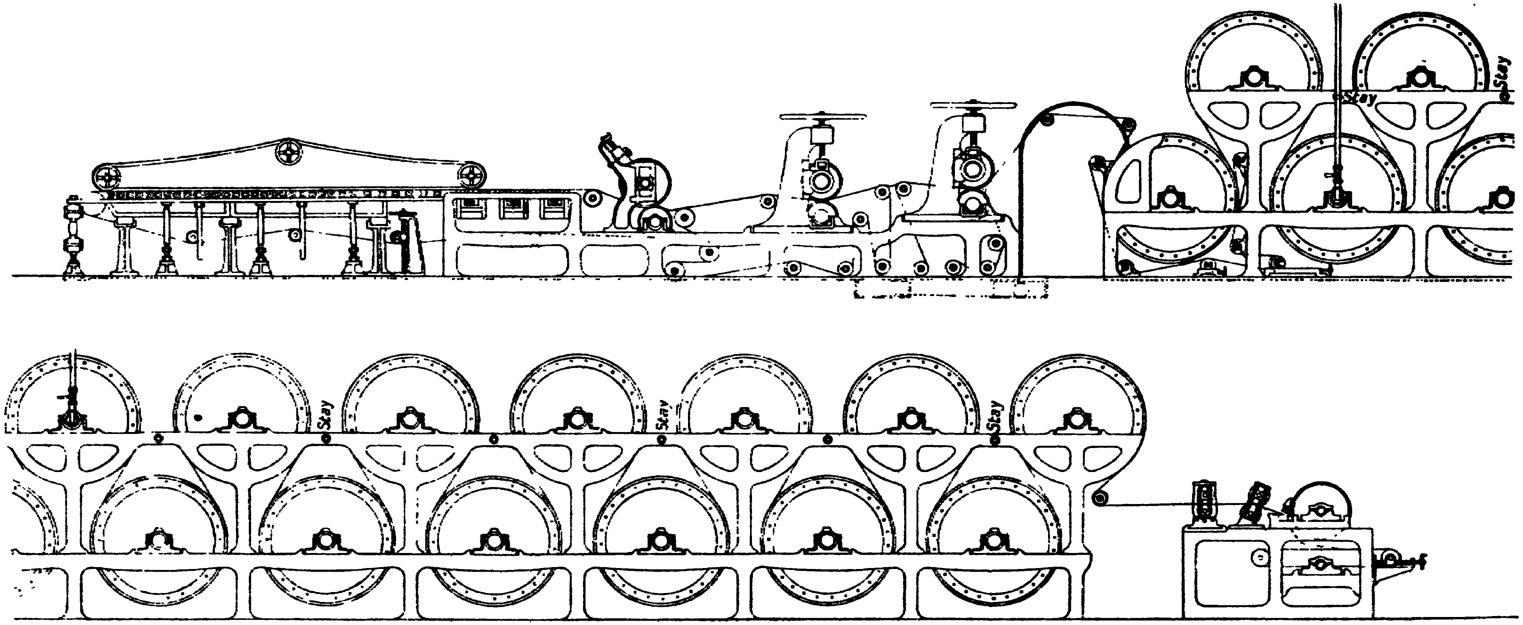


FIG. 115.—Revolving Digester—Bertrams'.

After digesting has been completed, the steam is shut off and the outlet door opened. The pressure within the boiler blows the pulp out of it and into a tank, where the stuff is strained and washed.

The digested, strained, and washed pulp is worked up into the form of thin sheets



"THE ENGINEER"

SWAIN SC

FIG. 116.—Machine for converting Wood Pulp into Dry Sheets—Bertrams.

on a machine of the Fourdrinier type. An example of such a machine—a pulp-drying machine as it is called—is illustrated in Fig. 116. This example is taken from the practice of Bertrams, Limited. Such a machine is not used exclusively for working up chemical wood pulp into sheets. It is employed also in converting raw pulp derived from esparto, sugar cane refuse, bamboo, &c., into dry sheets ready for export. It may be pointed out that the export of dry sheets of pulp rather than the export of the untreated raw material is economical in many cases, the deciding factors being the percentage of useful fibre contained in the raw material and the freight charges in force between the points of production and consumption. Sugar cane refuse and bamboo and, to some extent, wood are commercially practicable sources of paper-producing pulp, only provided the valueless stuff in them can be eliminated from them at the point of production.

As will be seen from the engraving, a pulp-drying machine is almost identical with an ordinary Fourdrinier. There are, however, quite a number of points of minor difference. The width of the wire is much the same as in an ordinary Fourdrinier. During the last twenty years Messrs. Bertrams have built pulp-drying machines, the wires of which have varied in width from 94 in. to 159 in. The speed of the wire, however, is considerably less. It depends, of course, upon the number of drying cylinders in use, but on the whole speeds of 50 ft. to 100 ft. per minute are most common. Our engraving shows a machine with eighteen drying cylinders set in two tiers. At times as many as fifty drying cylinders may, however, be employed, in which case they would be arranged in three tiers.

The strength of the pulp sheets being of no consideration, the wire frame of the dryer is not made to shake, as in an ordinary Fourdrinier. Our engraving certainly shows the wire frame supported on shaking joints. These are provided in order that the machine at any time may, if desired, be converted readily from a pulp dryer to a paper-making machine. Although the pulp sheets are many times as thick as a sheet of paper, and consequently have to be drained of considerably more water, the vacuum employed does not differ materially from that used in a Fourdrinier. It may actually be a little less. The explanation of this lies, of course, in the greatly reduced speed with which the sheet passes over the vacuum boxes.

Our engraving shows a dryer fitted with a pair of couch rolls and two pairs of press rolls. In connection with the latter, an important point of difference is to be noted. If one of the engravings of a Fourdrinier already given be studied—Fig. 51 on page 56 for preference—it will be found that while the paper is led through the first pair of press rolls in the direction from the wet end to the dry end, at the second pair it is led through in the direction from the dry end to the wet end. The paper, in fact, at the second press rolls executes an S-shaped turn, the rolls being situated at the mid point of the figure. The result of this is that the lower surface of the paper, the surface, that is, which shows the marks of the Fourdrinier wire cloth, is brought uppermost at the second press rolls, and is subjected to the pressure of the smooth metallic surface of the upper roll. This greatly assists the removal of the wire marks from the original lower surface, but it clearly complicates the wet felt arrangements, and may render necessary the use of power-driven leading rolls to move the felts. As the presence or absence of wire marks on wood pulp sheets is not of the least moment, the reversal made in the case of paper is not adopted. The pulp sheet is passed straight through both pairs of press rolls in the same direction. The wet felt arrangement, it will be seen from the engraving, is thereby simplified.

Coming to the drying cylinders, we notice that only the first of these is provided with a felt. The speed is so slow, and the web so stiff, that it is quite easy to lead the web over the drying cylinders without the assistance of felts on all the cylinders. The absence of felts, however, may on occasion have to be compensated for by arranging pressing rolls, one at the top point of each of, say, the three last drying cylinders in the upper tier. The use of such rolls results in a good hold being maintained on the sheet.

No smoothing rolls, no calenders, and no reel-up gear are provided on a pulp dryer. In place of the latter the web of pulp leaving the last drying cylinder is passed directly into a cutting machine. In our engraving this cutter is shown to consist, first, of a set of slitting knives, next a pair of draw rolls, and, thirdly, a cross-cutting knife drum. The pulp thus leaves the machine in the form of dry cut-up boards or sheets. The driving gear is much simpler than that designed for an ordinary Fourdrinier, as no provision for changing the speed to suit varying kinds of product is necessary.

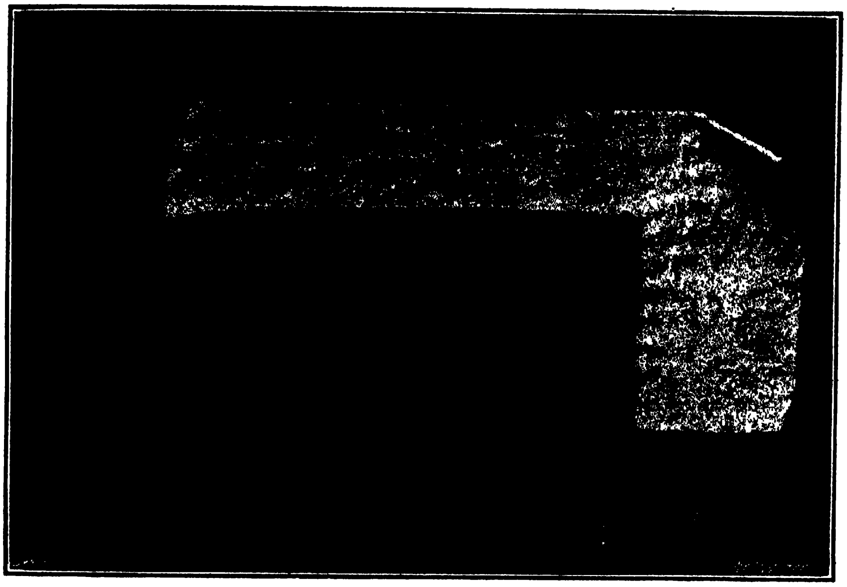


FIG. 117.—Samples of Wood Pulp—A, Mechanical; B, Sulphite; C, Soda.

We cannot discover that beyond the above appliances British engineers take any part in supplying the needs of the wood pulper. But if the producer of wood pulp is thus badly served, the user of the material has nothing to complain of, and there is no need for him to go outside Great Britain in order to obtain all the machinery required to convert wood pulp into paper.[1] Many of the machines, &c., so employed are identical with, or are but slight modifications of, those employed in the manufacture of paper from rags, grass, and so on. There is therefore no need for us to go into the details of their construction.

As in the case of other raw material, so it is with wood pulp; the exact practice followed in converting it into paper differs from one mill to another. It may, therefore, be of some value and interest if we conclude the present chapter with a brief description of the practice followed at a certain wood pulp mill[1] which we recently visited. This mill, we may say, supplies the paper used by several well-known daily, weekly, and monthly publications. The methods of working adopted at it, although typical, must not be taken as being the invariable practice of all wood pulp paper mills.

---

[1] Wood pulp is, of course, used for other purposes as well, a notable example being its conversion into artificial silk. Attempts have been made to use it as a basis for the production of photographic and cinematograph films, and as a substitute for cotton in the manufacture of explosives. The latter application, however, has not, we believe, been very successful.

The raw material employed at this mill is mechanical wood pulp, chemical wood pulp of both the soda and the sulphite variety, and "broke," that is the waste and spoilt paper and the clippings obtained from the cutting machines. This broke originates entirely within the mill itself, and is therefore only wood pulp in another form.

In Fig. 117 we illustrate samples of the three forms of pulp as received from abroad. All come in in the form of sheets measuring about 24 in. by 30 in. The two chemical wood pulps might readily be taken for rough cardboard, something less than $\frac{1}{16}$ in. thick. The sulphite pulp is white, or cream coloured. The soda pulp is light brown. Both appear quite dry to the touch, although in reality each contains about 2 per cent of moisture. The mechanical pulp is faintly yellowish in colour. The sheets are about $\frac{1}{8}$ in. thick, and are readily split up into numerous thin laminæ. They are further distinctly moist to the touch, and contain about 50 per cent. of water.

The paper produced from these pulps is not of one constant quality. To suit different orders, it may be a purely "mechanical" or a purely "chemical" paper, or something produced by an admixture of the two. Broke may be added to any in varying proportions.

A purely mechanical paper involves little trouble in the preparatory stages. The sheets, without any previous treatment whatever, are fed into a breaking engine provided simply with a roll, back fall, and mid feather, and are here softened and broken up into a sponge-like mass, the water used being the back water derived from the Fourdrinier. Broke in the form of wasted sheets, clippings, and scrapings from the rolls of the Fourdrinier will, if necessary, be tumbled into the breaker vat at the same time. The average charge is about 1100 lb. of dry stuff. The breaking process lasts for about twenty minutes. During this time the alum, clay, resin, &c., are added to the stuff, although in many mills these materials are not added until the beating stage is reached.

The broken stuff is then delivered direct into the beaters, of which roughly there are two for each breaking engine, since the beating process takes more time than the other. Bleaching is entirely omitted in this mill at least, so far as mechanical pulp is concerned. If the resultant paper be too yellow to suit the customer's requirements, a little mauve dye added to the pulp during the beating process will make the finished paper as white as it need be. In reality, of course, the mauve on top of the yellow makes it faintly grey. From the beaters the stuff is passed through a refining engine, whence it is delivered to the stuff chests in the machine house.

The paper thus produced is, of course, of a very poor quality, but it is thought good enough for many purposes. Its cheapness and the rapidity with which it can be produced in large quantities make it especially sought after by the daily Press.

The preparation of chemical wood pulp is conducted with greater pains. The sheets, sulphite, soda, or both, are broken up in a breaking engine, just as before, but with the addition of a measured quantity of bleaching liquor. It may be noted here that in some instances the inside of breaking and bleaching engine vats have been enamelled to prevent corrosion, contaminating the pulp. The practice does not seem to be altogether desirable, for we are informed that the enamel after a time has been found adhering to the first few drying cylinders of the Fourdrinier. At any rate, it seems to be superfluous. In process of time the bleaching solution, as was pointed out to us at the mill visited, lays down over the wetted surface of the vat the best of all enamels, presumably a deposit of lime.

---

[1] Not the *Daily Telegraph* mill.

When the stuff has been sufficiently "poached," or broken up, and has become thoroughly impregnated with the bleach, a valve at the foot of the vat is opened. The stuff may be so thick that it will not flow out through the opening. If this is so, some spent bleach liquor strained off from a previous charge, or "furnish," is mixed with it to reduce its consistency. The undiluted stuff is a sponge-like mass, of a colour, too, quite like that of a sponge, for the bleach has not, so far, had time to do its work.

We now pass to the floor below. Here we find the stuff descending from the breaking engine into a brick chamber provided with a tight-fitting door, and a floor formed of perforated plates of zinc and perforated tiles. The stuff is kept shut up in this chamber for at least twelve hours, and for twenty-four hours if there is time enough to spare. By the end of this period the bleach has entirely drained away from the fibrous stuff, and this now looks like white snow. No washing is thought necessary with this method of working, and that its omission causes no serious trouble is evidenced by the appearance of the Fourdrinier cylinders, and by the fact that no complaints, or so we understand, have ever been received from customers which could be traced to the presence of free bleach in the paper. No "anti-chlor," that is sodium thiosulphite or sodium sulphite, it may be added, is used.

On the same floor as these straining chambers we find the bleach mixers. These are of the type described in our third chapter. The practice at the mill visited is to use 700 lb. to 800 lb. of bleaching powder to 2000 gallons of water. The strained liquor is pumped to tanks situated above the level of the breaking engines. To similarly situated tanks the spent liquor passing away from the pulp straining chambers is also pumped for use as mentioned above.

At the mill in question the straining chambers are on the ground floor. Economy of labour would no doubt have resulted if the breakers had been on the second floor, the strainers on the first, and the beaters on the ground. As it is, the breakers and beaters are both on the first. The workmen, therefore, load the strained and bleached stuff into barrows and carry it upstairs to the beating engines. The beating process is in no wise different from that referred to in connection with mechanical wood pulp. Water has to be added to the strained bleached pulp before it can be beaten. This may be the back water from the Fourdrinier. Refining follows beating just as before.

Thereafter the treatment of either pulp is in no essential different from that accorded rag, grass, or other pulp, exactly the same form of strainers, Fourdrinier and calenders being used to convert it into finished paper.

CHAPTER XV

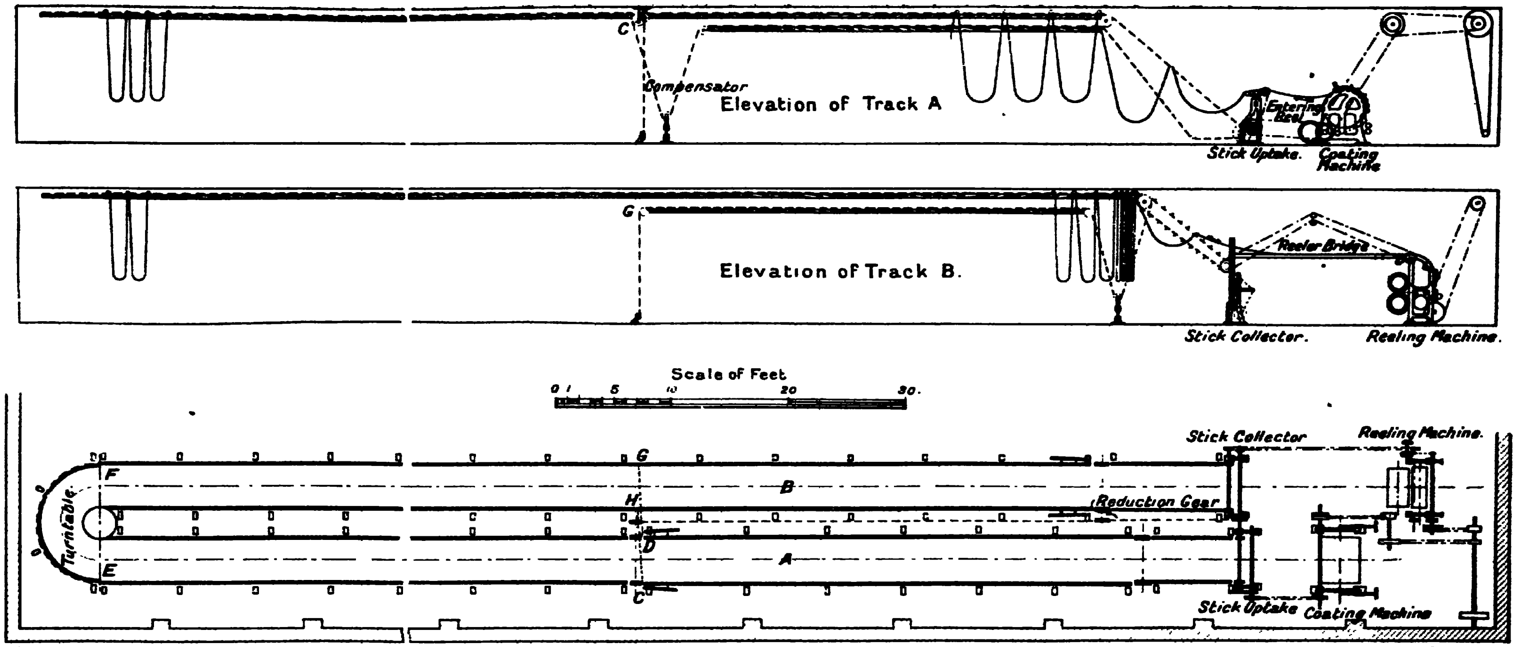
THE COATING OF ART PAPER

For very many purposes paper, after being calendered and slit, is completely finished and ready for the user. But were we to stop our work at this point we would be neglecting an important part of the papermaker's work, namely, the production of coated "art" papers. This work is to be regarded as part of the papermaking process proper, and those manufacturers who lay themselves out to supply the demand for coated art papers usually conduct the coating operations at the mill where the paper to be coated is produced. On the other hand, art paper for printing purposes must be regarded merely as one of a large class of coated papers. We may have paper coated with tin, lead, brass, gold, and other metals for decorative and wrapping purposes, with "carbon" for type-writing, with sand and glass for the use of woodworkers, with gum, with photographic emulsion, and so on. These papers are the products of separate industries, and beyond supplying the suitable raw paper, the papermaker has nothing to do with them. Yet in many respects the plant used in producing such papers is closely similar in principle and frequently in design to that used by the papermaker for turning out coated art paper.

In this and the remaining chapters we propose to discuss the construction and working of selected examples of the machinery and plant used in the manufacture of coated paper. It is quite impossible for us to cover all classes of coated paper, for, or so we gather, not all the machinery used is made in this country. We find it is necessary to restrict ourselves to a discussion of the manufacture of, first, coated art paper, and, secondly, of coated photographic paper. These are probably the two most important branches of the subject. Before the war much of the machinery used in them and in the other branches came from Germany. It is satisfactory to notice, that a reversion to this state of affairs will not be necessary.

The papermaker and the printer know two kinds of "art" paper—genuine and imitation. With the imitation material we are not here concerned, for it is not a coated paper. It is usually a paper made from esparto and sulphite wood, the former predominating to the extent of four to nine times the amount of the latter raw material. To this composite pulp there is added in the beating engine as much china clay or other mineral matter as the pulp will hold. In the dried finished state this superloading may amount to 24 or 30 per cent. of the total weight of the paper. The paper is made, dried, and calendered in the usual way, the calendering being carried out with the surface of the paper damp. The result is a paper, if such a term can be given to a substance of which more than a quarter is mineral matter, which closely resembles genuine art paper, and which, being cheap, is used for circulars and similar matter of a temporary nature. Imitation art paper in some qualities is apt to be weak.

Genuine art paper is finished and dried paper coated with china clay or "satin white," the latter being a prepared compound of aluminium sulphate and lime. An adhesive such as glue or casein—a constituent of cow's milk used in an extraordinarily wide variety of industries—is added to the coating solution. The raw paper is coated



"The Engineer"

Swain Sc.

Fig. 118.—Typical Art Paper Coating and Drying Plant—Mather and Platt.

on one or both sides, but the coating is confined to the surface. The paper is not saturated throughout with mineral matter, as is imitation art paper. In use the impression of the printer's type or engraver's block is confined to the coat of mineral matter. The ink does not penetrate into the fibrous part of the paper, which part is to be regarded as a mere carrier, and for this reason is sometimes very poor material. If a piece of genuine art paper be soaked in warm water the coating, if glue is the adhesive used, can be dissolved off, and with it will come any printed matter on the paper. To some, art paper is unpleasant to handle, but it is more or less a necessity nowadays if best advantage is to be taken of the block-maker's art. The finer the screen used in making a half-tone block the more detail will there be in the impression, and the smoother must be the surface of the paper used by the printer.[1]

The general lay-out of what may be regarded as a typical art paper coating plant is illustrated in Fig. 118. This engraving represents an installation recently supplied by Mather and Platt, Limited, Newton Heath, Manchester. Looked at generally, the plant may be said to consist of several distinct parts. First we have, occupying a very small part of the total space, the coating machine proper. This machine takes in the reel of dry paper as delivered from the Fourdrinier, unwinds it, applies the coating substance in a liquid state to one side of it, and spreads and brushes the aqueous mixture evenly over its surface. The paper being now weak and wet, has to be handled with great care in order to avoid tearing it and disturbing the evenness of its coated surface. It cannot, of course, be reeled up until it is quite dry. To dry it we cannot employ a machine of the same type as that generally used for drying tub-sized paper. In such a machine, as reference to Chapter XII will show, the paper while drying is carried round a large number of barrels in such a way that, in general, alternate barrels support the paper on alternate sides. This is a very desirable feature in a machine for drying paper after it has been tub-sized, but after the paper has been coated we must not touch the coated side until it is quite dry. Further, the paper should be subjected as little as possible to any action equivalent to rolling and unrolling it on a reel, for if it is bent about too much there is great danger of the coating being disintegrated.

The method adopted to support the paper until its coating is quite dry is to hang it over a large number of sticks in a series of festoons or loops, and to cause these sticks to travel continuously along an overhead trackway so as to carry the festoons with them. During the passage along the trackway the loops are subjected to the influence of hot air arising from the floor of the building. The trackway need not be all in one straight line. The time required to dry the paper would, if the trackway were in one length, result in our having to provide a coating room of inordinate length. By an ingenious yet simple turntable arrangement the festoons can be taken off one part of the trackway and sent back to the coating machine end of the building on a parallel track. Our engraving shows a two-track arrangement. There may, however, be any number of tracks and turntables, the exact arrangement being made to suit the space available.

The festoons, after reaching the end of the last track, have to be taken down, and the paper, now dried, has usually to be slit into two or more widths and reeled.

To get the wet and weak paper off the coating machine on to the beginning of the trackway is a delicate operation. Fig. 119 shows the arrangement adopted by Mather and Platt, Limited, at this end of the plant. Between the coating machine on the

---

[1] The half-tone illustrations in this book are made with screens having 120 lines to the inch. The best class of daily newspaper can hardly do with screens finer than 70 lines to the inch. Screens of 250 lines to the inch are sometimes used, but 175 lines is about the finest division in common employment.

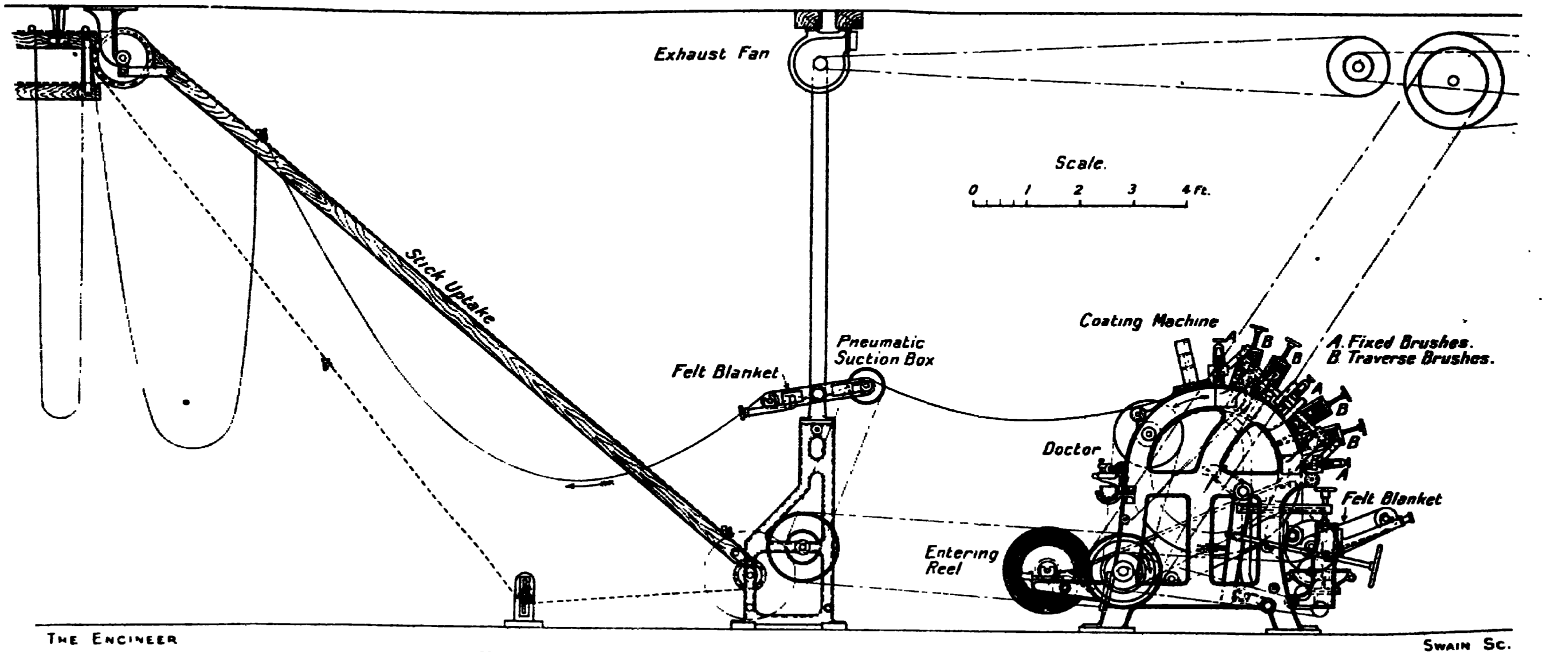


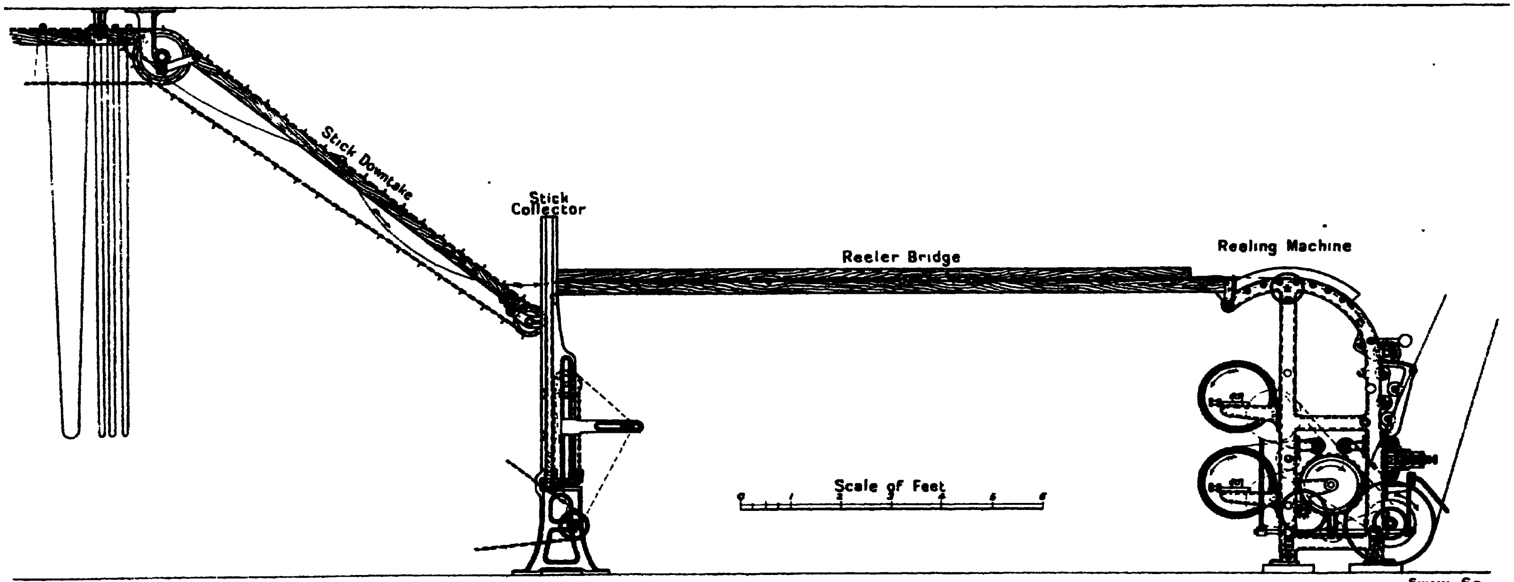
Fig. 119.—Coating Machine and Uptake End of Trackway.

right and the commencement of the overhead trackway on the left the weak and wet paper has to be supported on some sort of roller which will apply power to the web to move it forward. We cannot, of course, fix a co-acting roller above the first to give the necessary driving "nip," for this would disturb the moist coating on the upper side of the paper. But if we cannot thus apply pressure to the coated upper side we can apply a vacuum to the uncoated underside. Accordingly, the supporting "roller" takes the form of an endless felt band mounted on a pair of spindles, one of which is driven by power, while the other is adjustable to stretch the felt. The paper rests upon the top of the upper stretch of the felt. Beneath this stretch and between the two spindles is a suction box, the top of which is closed by a perforated steel plate. The vacuum is created by an exhaust fan and causes the paper to be sucked down on to the felt, so that the felt not only supports the paper but drives it.

The festooning device is also shown in Fig. 119. Imagine the commencing end of the web carried over by hand from the suction box and hung over a stick lying across the beginning of the trackway. The portion between the suction box and the stick hangs in a flat curve, and on each side of this, so that the paper falls freely between them, is arranged an upward sloping rail of wood, with a chain pulley at each end. An endless chain passes along the upper edge of each rail, round the pulleys at its ends, and round a third pulley fixed to the floor. At equal distances apart on this chain three special links are provided, these links being in the nature of small fingers projecting from the rest of the chain. The two chains are arranged to work in unison. As a pair of the fingers comes round the pulleys at the lower end of the rails a stick is automatically pushed across them. This stick, travelling up, lifts the web of paper between the rails into a festoon, and on arriving at the top chain pulley is engaged by fingers projecting from travelling chains provided on the overhead trackway.

At the other end of the trackway the festoons have to be taken down from it, the sticks collected, and the paper, now dry, passed into the reeling machine. This end of the plant is shown in Fig. 120. The arrangements adopted are practically the same as at the entering end, except that the downcoming pair of endless chains runs in the reverse direction and is provided with many projecting fingers instead of only three. The sticks, it will be gathered, tumble off round the lower chain pulley into a stick collector, in which they are stored until they are required at the stick uptake at the upgoing end of the trackway. The stick collector and the stick uptake are situated in line, and from the collector the sticks are automatically pushed across one at a time as required on to the upgoing endless chains. The paper, freed of the support of the sticks, is taken over a reeler bridge—merely a horizontal ladder—into the reeling machine. The reeler bridge serves no purpose other than that of supporting the paper across the gap between the stick collector and the reeler. This gap arises because it is desirable to have the stick collector in line with the stick uptake, and because it is usually impossible to arrange the reeling machine in line with the coating machine. The reeling machine is placed farther from the track end than the coating machine rather than the reverse way, because at the reeler end the paper, being dry, is better able to be led over the unavoidable gap than it is when wet.

The trackway is simply a series of parallel wooden rails hung from the ceiling and supporting travelling chains, which at short regular intervals are provided with upward-projecting fingers to engage the sticks. There is considerable interest in the arrangements made in connection with the driving of the trackway chains. The speed of the paper through the coating machine is 120 ft. to 140 ft. per minute. This must also be the speed at which the paper is reeled up at the other end of the plant if the quantity of paper on the trackway at any instant is to be constant. The speed of the



"THE ENGINEER"

SWAIN SC

FIG. 120.—Downtake End of Trackway and Reeling Machine.

chains must be made such that 120 ft. to 140 ft. of paper are led past any given point on the trackway per minute, that is to say, the number of festoons passing this given point in a minute, multiplied by the length of paper in each festoon, must be equal to the speed of the coating and reeling machines. There is no movement of the paper over the sticks, so that the length in each festoon is constant from beginning to end of its journey on the trackway. Hence the number of sticks passing any point on the trackway per minute must be constant and equal to the linear speed of the paper through the coating machine, divided by the length of paper in each festoon. This figure, then, is settled by the output desired from the plant and the head room available.

It is not desirable that the sticks should be close together on the trackway at the commencement of the drying, for the loops, when being formed, are apt to swing, and as the coated side is inwards, the two sides of a festoon must not be allowed to touch. Later on, when the paper is somewhat drier, and when the motion has become steady, it is desirable to reduce the distance between the sticks, for by so doing a given length of trackway will accommodate more paper than it otherwise would. Where the change in the distance between the sticks is made the linear speed of the travelling chains has to be altered in direct proportion. If, for instance, the distance apart of the sticks at the beginning is 4 ft. and the speed of the chains at this point is approximately 38 ft. per minute, as in the plant illustrated, then, if we change the distance apart of the sticks to 1 ft. 9 in., we must reduce the speed of the chains to approximately 17 ft. per minute. This secures the condition that the number of festoons passing any given point per minute is constant, and, in this case, equal to 9½. The length of paper in each festoon in the plant illustrated, it will be seen from this, is about 12½ ft. to 14¾ ft.

The change in the distance apart of the sticks and in the speed of the chains is, in Fig. 118, made at the points C D. At these points the two chains on the first portion of the trackway pass down to weighted compensators guided in brackets fixed to the floor, and from them pass up to a pair of overhead return rails, and are so led back to the entering end. The remainder of the trackway is operated by a single chain. This chain starts, let us say, at the point C in the plan, and passes along the outer rail of the first portion of the trackway until it comes to the point E. Here, in order to avoid the turntable, it passes vertically downwards to a pulley fixed to the floor. At the floor level it goes across along the line E F, and rising up passes over a pulley at F on to the outer rail of the second portion of the trackway. Proceeding to the downtake end of this rail, it is led down to a compensator and up again to an overhead return rail. At the end G of this it goes over a pulley, down to the floor, across and up to the point D on the inner rail of the first portion of the trackway. Passing along this rail, it is led round a horizontal pulley forming the nave of the turntable, and so reaches the inner rail of the second trackway portion. Reaching the end of this, it is diverted back round a compensator and along a return rail to the point H, whence it passes down across and up to the point C. There is no reason why two separate chains cannot be employed after the break at C D, just as two are employed before this break. In our next example it will be found that two such chains are employed. Later on, in connection with another pair of examples, we will discuss the merits of the two methods.

The outer circumference of the turntable in Fig. 118 is formed by a separate chain running round the semicircle from E to F, passing down at F to the floor, going across and rising up to E. This chain is driven at an increased rate so chosen that in passing round the turntable the sticks shall be aligned radially.

To drive the whole of this plant some five horse-power is required, the coating machine taking one and a half horse-power, the reeling machine two and a half, and the trackway one.

CHAPTER XVI

THE COATING OF ART PAPER (*continued*)

As a second example of an art paper coating plant, we give in Plate V the complete lay-out of an installation erected recently by Masson, Scott and Co., Limited, Fulham, London, S.W. This example is particularly interesting because its trackway has no fewer than five bends in it. Of course, it is always desirable to have as few turntables as possible, for they do not tend to simplify or cheapen the plant. The plant has, however, in most cases to be designed to fit into a given limited space. Our engraving shows how even the most unlikely shape of building may be utilised for the purpose. Within a space of some 64 ft. by 44 ft. there has been arranged a coating machine, a stick uptake, a trackway in six straight lengths aggregating about 210 ft., five turntables adding some 11 ft. to the effective drying length, a stick downtake and reeling machine, and a five-roll calender with the necessary re-reeling appliance.

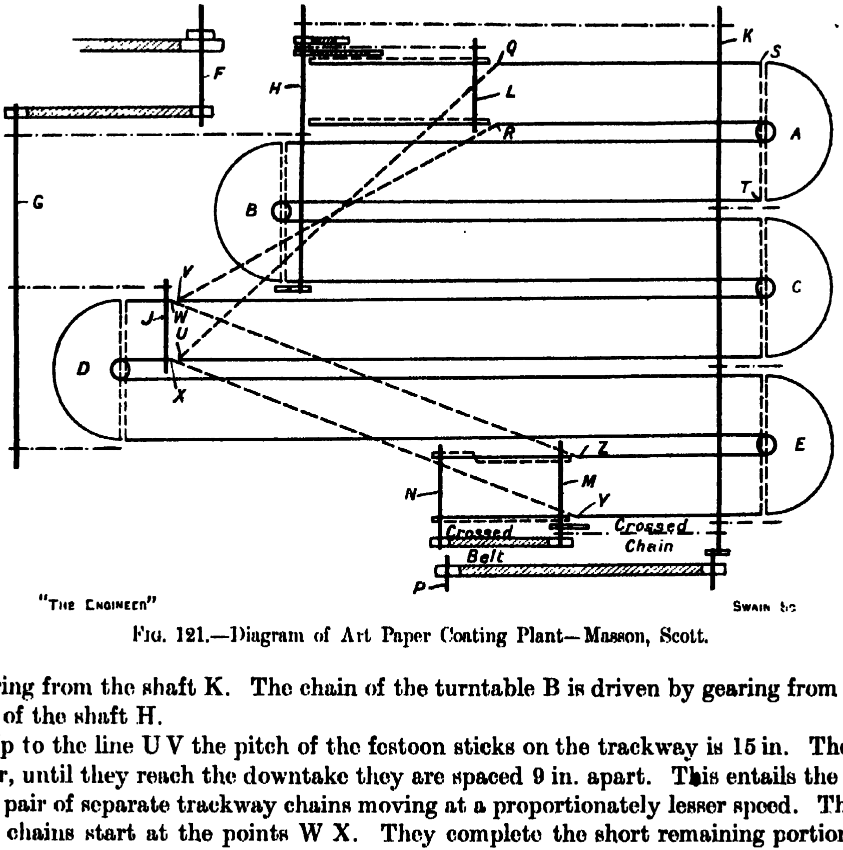
Much of the technical interest in this plant centres round the manner in which its parts are driven. As it is somewhat difficult to follow the driving details in the general arrangement, we have picked out the essential features in diagram form in Fig. 121. In this engraving the five turntables are marked A to E. Nine countershafts F to P are shown. The chains of the trackway and turntables are shown in full lines over the working stretches and in dotted lines over the return or idle stretches. Chain drives are shown by chain dotted lines and belt drives are indicated by shading.

By reference to the original drawing it will be seen that between the first countershaft—F in Fig. 121—and the electric motor driving the whole plant there are two countershafts, the three belts giving a speed reduction of over 150 to 1. A motor running at a high speed, 1655 revolutions, is chosen for the sake of its economy and small size. To reduce this speed to that required for the plant spur gearing might be used. Such gearing has been tried, we understand, for paper coating installations, but it is found that unless the gearing is very carefully made and looked after the image of its teeth will appear on the coated surface of the paper.

The countershaft F drives the shaft G by belt. The latter shaft drives the countershafts H and J by chain. The shaft H drives by chain the shafts K and L. The shaft K drives the shaft M by a crossed chain and the shaft P by gearing and belt. The shaft M drives the shaft N by crossed belt. From the countershaft F a belt passes down to the coating machine. This machine delivers the paper to the festooning plant at the rate of 40 ft. per minute. As in the previous example the damp paper is pulled off the coating machine by a suction arrangement. The fan creating the required vacuum is driven by belt from the first of the three motor countershafts. The endless felt beneath which the vacuum acts is driven by belt from the shaft H. It will be noticed that after leaving the vacuum felt the paper is led over a power-driven barrel before it is lifted up by the sticks. This barrel is necessary in view of the length of the uptake. It is also driven by belt from the shaft H.

The uptake chains are driven through gearing from the shaft L. The festoons are passed on to the two trackway chains on the line Q R. The chain commencing at Q passes round a runner at S, descends to the floor, passes across and rises over a pulley at T to form one side of the second portion of the trackway. The chain starting at R passes round the central pulley of the turntable A and forms the other side of the second trackway. The same chains reappear on the third trackway and on the fourth trackway up to the points U V. At these points they are led over two pulleys driven through gearing from the shaft J and so down to the floor and across and up again to the points Q R respectively.

The outer chains of the turntables have to be driven separately at a proportionately faster rate than the chains of the main trackway, so that the sticks in passing round them shall take a radial alignment. The turntable chains run around the outside of a curved guide. Each is separate from the others and returns to its starting-point by way of the floor. The chains of the turntables A and C are driven by chain and gearing from the shaft K. The chain of the turntable B is driven by gearing from the end of the shaft H.



"THE ENGINEER"

SWAIN Sc

FIG. 121.—Diagram of Art Paper Coating Plant—Masson, Scott.

Up to the line U V the pitch of the festoon sticks on the trackway is 15 in. Thereafter, until they reach the downtake they are spaced 9 in. apart. This entails the use of a pair of separate trackway chains moving at a proportionately lesser speed. These two chains start at the points W X. They complete the short remaining portion of the fourth trackway, form the whole of the fifth trackway and all the short sixth one. They pass over wheels at Y Z, which are driven by gearing from the shaft M and return by the floor to the starting-points W X. The turntable D is driven by chain and gearing from the shaft G and the turntable E from the shaft K in a similar manner. The downtake is driven at its lower end by the shaft N. The reeling machine at the foot of the downtake is driven by belt from the countershaft P. The calender is separately driven by an electric motor. It is necessary to wind and unwind the paper between the festooning plant and the calender because the latter to perform its work efficiently and with the best result must run considerably faster than the former.

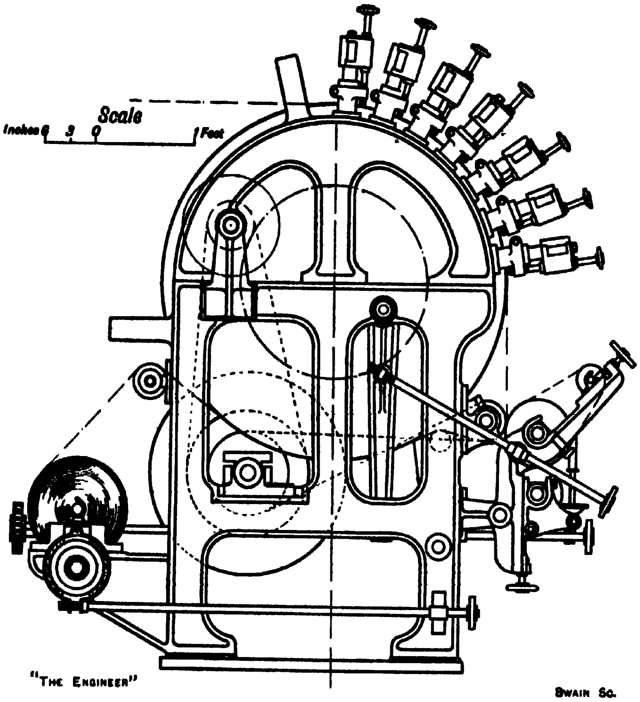
It will be noticed that the pulleys at the centres of the turntables D and E are 15 in. in diameter, while those of turntables A, B and C are 18 in. There is no mathematical reason, so far as we can learn or discover, why the turntables on the slower section of the trackway should thus be smaller than those on the faster section. The reason why in this installation there exists a difference is, we believe, to be traced in the natural desire of the makers to work in standard fittings and wheels.

The design of the uptake and downtake of a festoon machine is a matter requiring careful consideration. From the mathematical point of view the problems involved are cumbersome and complex and require for their solution an acquaintance with the properties of catenaries. Practically it is a matter for trial and error and for adjustment after erection. A power-driven drum disposed between the uptake rails, as in the example now being dealt with, if its final position is left to the erector, greatly simplifies the designer's work. The objects to be attained in designing the uptake are, first, that it shall feed the trackway with festoons just at the required rate, and, secondly, that while the festoons are being formed by the uptake the paper shall not be allowed to trail at any instant on to the ground. Similar considerations have to be kept in mind in designing the downtake.

Taking the case of the plant illustrated in Plate V, we find that the output desired from it is 2400 ft. of paper per hour, and that considerations of head room limit the length of paper in each festoon to about 24 ft. To maintain the output, therefore, 100 sticks must pass any point of the trackway every hour. As the pitch of the sticks is fixed at 15 in. on the earlier portion of the trackway and at 9 in. on the later, it follows that the speeds of the chains on the two sections are 1500 in. and 900 in. per hour respectively, or 2 ft. 1 in. and 1 ft. 3 in. per minute.

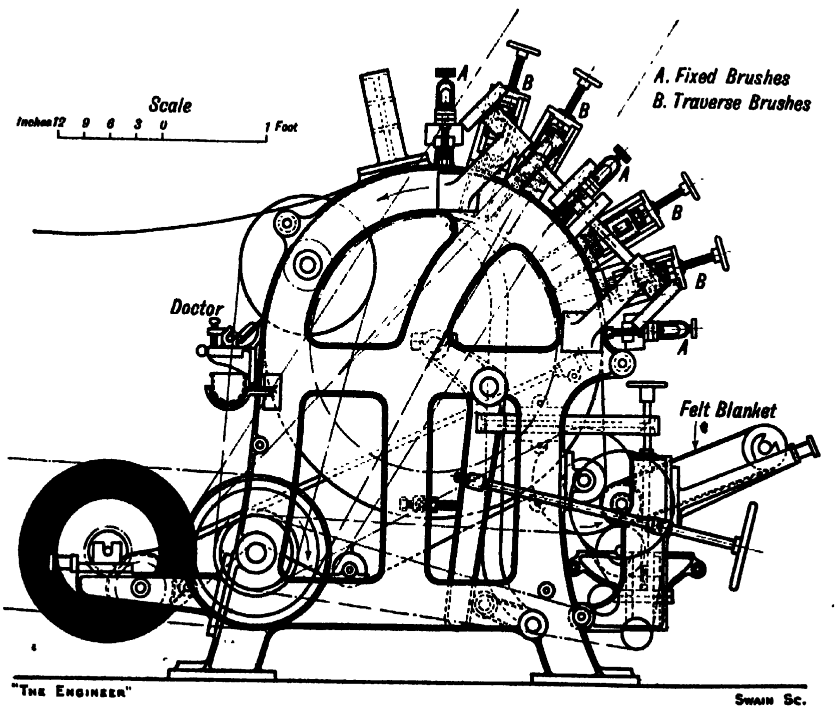
It is clear that 100 festoons must be formed by the uptake per hour and a like number taken down by the downtake. In general the length of the uptake and downtake can be fixed to suit the space available. Their highest points, of course, are fixed as soon as the level of the trackway is determined, so that their length becomes dependent on their angle of slope. This in turn has to be made to suit the available floor space. In the example now being dealt with matters have been so fixed that each endless uptake chain has a length of about 42 ft., while the downtake chains measure about 29 ft. These lengths having been fixed, we have next to settle upon a suitable number of fingers for the chains. It is clear that this number once settled fixes the speed of the chains. Thus, in the example being dealt with, there is one finger only on each uptake chain. As the output of the plant is 100 festoons per hour, the uptake chains must clearly make 100 complete revolutions per hour. As the length of each is 42 ft., this implies that their speed is 70 ft. per minute.

At the downtake end matters are arranged differently. It is found desirable to provide for the possibility of the festoons arriving at the top of the downtake a little earlier or a little later than they should if they behaved with mathematical regularity. That some latitude is necessary is obvious when we investigate the influence of alteration in the length of the various driving and carrying chains produced by thermal and other changes. The uptake chains run in close agreement with the trackway chains. The downtake chains do not. The latter run at 14·4 ft. per minute, or, say, one complete revolution in two minutes. As they have to take down 100 festoons per hour, there should be three or four fingers in each downtake chain. In reality there are seventeen on each, so that on the average there are four idle fingers between each one occupied by a stick. The arrangement is therefore such that at whatever



"The Engineer"

Swain Sc.



"The Engineer"

Swain Sc.

Figs. 122 and 123.—Art Paper Coating Machines by Mather and Platt and Masson, Scott.

time a stick reaches the top of the downtake a pair of fingers on the downtake chains is ready to receive it, and will do so without requiring the stick to fall through a greater distance than 1 ft. 8 in., measured along the slope of the downtake.

The coating machines, apart from the trackway and its details, possess considerable interest. In Fig. 122 we illustrate the Mather and Platt coating machine on an enlarged scale, and in Figs. 123 and 124 we show the Masson, Scott machine. In both instances, it will be seen, the paper is led round a power-driven cast iron drum, which is 4 ft. 3 in. in diameter in the example shown in Fig. 122 and 3 ft. 6 in. in the case of Fig. 123. The paper makes contact, roughly speaking, with the right-hand half circumference of this drum, and is led off from the top on to the trackway. Midway over the first quadrant of contact the paper is taken off the drum and led round a small power-driven roller. At this point it receives its coating solution from an endless felt band, which in turn is fed with solution by a roller dipping into a tray. All the rollers and the tray are usually made of copper.

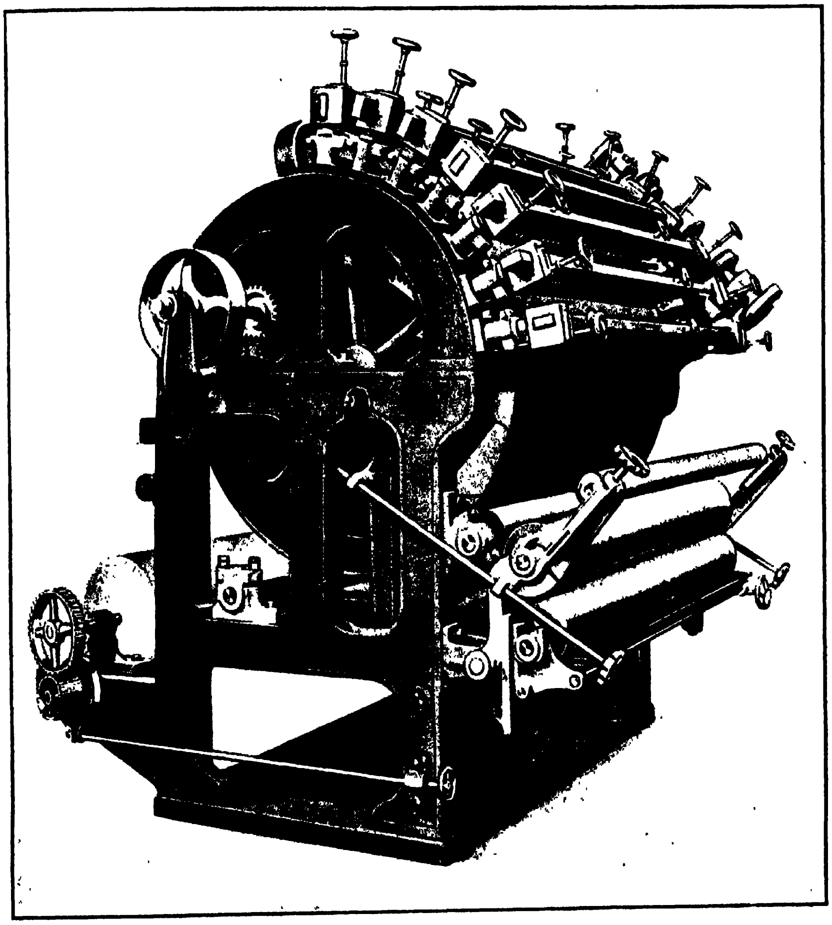


FIG. 124.—Coating Machine—Masson, Scott.

Over the upper quadrant of the drum the paper is subjected to the action of seven brushes, which spread and smooth the coating material in an even manner. Certain of these brushes are fixed, although all are capable of being adjusted to compensate for wear. In both instances the fixed brushes are the first, the fourth, and the seventh. The remaining four are given a short-throw reciprocating movement, the motion being derived from a power-driven shaft lying at an angle and tangential to the drum. The hair in the brushes is graded. Referring particularly to Messrs. Masson, Scott's machine, we find that the brush which the paper first passes under is composed of hard boar bristles. The succeeding four brushes carry soft boar bristles. The last two consist of fine badger bristles.

In order to facilitate leading the web of paper through the machine when it is being started up, provision is made for lowering the drum away from the brushes. In both instances this is effected by carrying the drum spindle at each end in a bell-crank lever fulcrumed on the main frame. The ends of the long arms of these two levers are acted upon by rollered lever arms on a hand-operated cross shaft. Reference to Fig. 124 will show that the two felt rollers, the dipping roller and the tray are all carried between a pair of brackets which are pivoted to the main frame, whereas the power-driven contact roller, in passing over which the paper receives its coating from the felt blanket, is journalled directly on the main frames. The two pivoted brackets referred to are tied back by screwed shafts to nuts on the sides of the long arms of the bell-crank levers supporting the drum shaft. By this arrangement the movement of the bell-crank levers to lower the drum away from the brushes simultaneously causes the felt blanket to move back from the contact roller, thus permitting the paper to be readily passed round the drum. At the same time the handles on the ends of the screwed shafts permit the position of the hinged brackets to be adjusted so that the desired amount of pressure between the blanket and the contact roller may be attained.

Both machines are provided with a hand-operated brake for checking the speed of unwinding of the roll. In the Mather and Platt machine a "doctor" is arranged across the rear of the drum. This scrapes off any of the coating solution which may chance to gather on the drum surface, and delivers it into a trough immediately below. It will also be noticed that in this machine the lower felt blanket roll is positively driven by means of a belt, whereas in Messrs. Masson, Scott's machine it is not driven otherwise than by its pressure against the paper as it passes over the contact roller. The belt drive adopted by Messrs. Mather and Platt for the lower blanket roller is such that its presence does not prevent the hinged parts from being opened. This is secured by causing the belt to bend round a pair of rollers situated close to the hinge axis.

CHAPTER XVII

THE FINISHING OF COATED ART PAPER

THE paper as coated in the manner we have described has a dull, rough, somewhat unfinished surface. Its appearance is converted to that familiar to the reader by passing the web through a calender. So far as we know the design of calenders for finishing coated art paper need be in nowise different from that of those intended for dealing with ordinary uncoated paper, such, for example, as those we described in Chapter XIII. Certain of the calender rolls may be steam heated, but this is optional, just as it is with ordinary paper. The temperature of the heating steam—if steam heating is adopted—is, however, usually a little less for coated than for uncoated paper. Such heating does not affect the adhesive material in the coating to any appreciable extent. The passage through the rolls is too rapid to result in the melting of the gelatine or other adhesive, as showing which it may be remarked that the web can be re-reeled without causing trouble immediately after it has left the last calender roll. It is to be noted that ordinary paper is best calendered when slightly damp, and that for this reason dampening machines of special design are frequently to be found in the calender-room. Such a method of working is not practicable with coated art paper, for if this is not thoroughly dry when passed through the calender some of the coating will inevitably adhere to the rolls. It may be doubted whether dampening, were it practicable, would achieve any good result, for it is obvious that the calendering of a coated art paper is mechanically quite a different process from the calendering of ordinary paper. Thus the effect is on the coating itself rather than on the fibrous backing, the result being that the clay of the coating is compressed well in among the fibres.

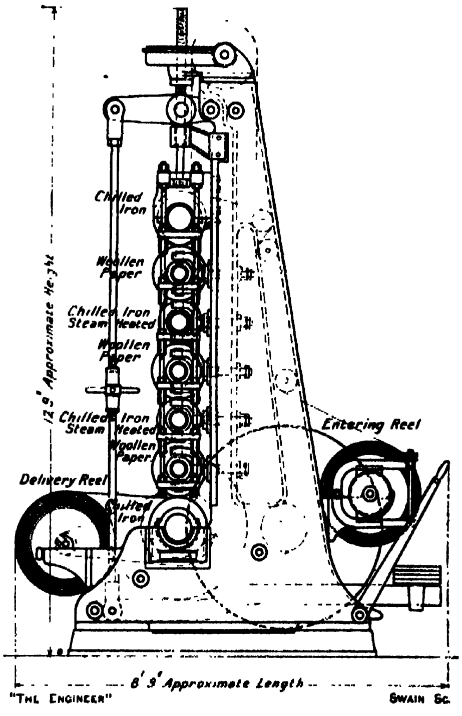


FIG. 125.—Calender—Mather and Platt.

As we have already dealt with calenders for ordinary paper at some length, we need here say little about calenders for coated art paper. We may, however, briefly refer to one design, not already mentioned, which has found frequent application on both classes of paper. This design, by Mather and Platt, Limited, is illustrated in end view in Fig. 125. This is a seven-roll calender having four chilled iron rolls and three of "woollen paper," arranged alternately. The two intermediate iron rolls are steam-heated. Woollen paper, it may be remarked, is a special paper free from every trace of metallic or other foreign matter. In the process of making these woollen paper rolls, the cylindrical surface is accurately finished by grinding. The calender illustrated is driven by belt through the lowest roll, but it may of course be driven through cut gearing from an electric motor or in any other manner. As usual, the weight of the rolls is supplemented by a pair of weighted levers, which transmit their load on to the journals of the top roll, and which can be thrown out of action by means of a hand lever. Also, as usual, provision is made for separating the rolls, so that when stationary the iron rolls will not cause flats to develop on the paper rolls. For this purpose the thrust rod bearing on each top roll journal, through which the additional loading is transmitted, has suspended from it a pair of rods connected by six cross pieces, one below each roll end except the lowest. In the working position the distance between the roll end and the top of the adjacent cross bar increases progressively from the top to the sixth roll, so that on the thrust rod being raised, as may be done by a chain and worm wheel arrangement, the rolls will be separated by uniform amounts. The manner in which the journal bearings for the five intermediate rolls are supported and tied back to the standard should be noticed. The object is to secure the result that each two contacting rolls bear together along their whole length without the binding of the roll journals in their bearings.

The coated side of the paper makes contact only with the surface of the iron rolls, by the pressure of the smooth hard surface of which the calendering effect is obtained. It will readily be seen that for this to be so the coated side must be the underside of the paper as it leaves the reel-off. It is also the underside of the web passing on to the reel-up. At times paper coated on both sides is required. Such paper could be calendered on a machine of the type illustrated by passing it twice through the rolls, the entering reel being turned upside down on the second occasion. Alternatively, a calender can be used, the arrangement of the rolls of which is such that two paper or two iron rolls are placed together at one point, so that at this point the calendering is changed from one side of the paper to the other, thus permitting the operation to be completed at one passage.

After calendering, the paper is ready for the market. Its surface is smooth, but not necessarily glossy. For some purposes a distinct gloss is required on the surface of art paper, a greater gloss, that is, than can be obtained by means of the calender rolls. To secure this desired finish the coated surface is brushed and polished with finely divided French chalk.[1] The brushing machines used for this purpose were before the war obtained largely, if not exclusively, from Germany. There is now, however, no need for papermakers to go abroad for these machines, as they are being made to-day by at least two English firms, of which one is the Glossop Ironworks Company, Limited, of Surrey Street, Glossop.

The first machine of this type made at these works is illustrated in Figs. 126 and 127. This machine is capable of taking in paper up to 40½ in. wide and finishing its surface at one passage. The speed of the paper is 55 ft. per minute, so that at its full width the machine has an output per hour of 2640 sheets, measuring 20 in. by 30 in., or 5·3 reams of 500 sheets each. The machine as shown in Fig. 127 consists of an open cast iron frame carrying reel-off brackets at the right-hand end, reel-up brackets at the left, three roller-like brushes on top, and a chalk distributing box parallel with the brushes. The reel-off spindle is not driven by power, and is braked as usual.

---

[1] French chalk is a variety of steatite or soapstone, and is chemically a hydrated silicate of magnesium.

The reel-up spindle is driven by belt through a slipping friction clutch, which enables the linear speed of the paper to be kept constant as the reel grows in size.

The paper leaving the reel-off passes in succession under each of the three brushes, being held up to the lower half circumference thereof by three groups of four small rollers. These rollers are carried in slidable bearings, so that they may be adjusted radially relatively to the associated brush. This adjustment permits of wear on the bristles being compensated, and of the correct amount of pressure of the paper against the bristles being obtained to suit specific requirements. The roller ends on both sides in each group are embraced by a cam-slotted sector plate pivoted on the associated brush spindle. The radial adjustment of the rollers is effected by a partial rotation of these sector plates through the intermediary of a hand wheel and worm shaft. The two sector plates of each roller group are arranged to be adjusted simultaneously by connecting the hand wheel shaft through mitres and a cross shaft to a corresponding worm shaft on the opposite side.

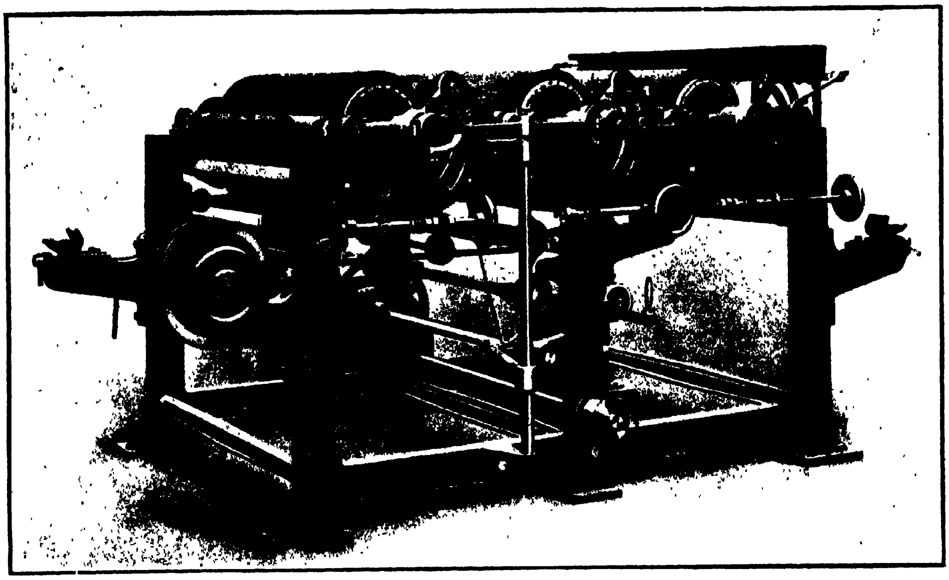


Fig. 126.—Brushing Machine Glossop Ironworks.

The main driving shaft is situated near the floor level, directly beneath the centre brush. On the near end—Fig. 126—this shaft carries a small belt pulley from which power is taken to the friction clutch pulley of the reel-up device. On the far side the main shaft carries a fast and a loose pulley and a group of three fast and flanged pulleys. From the latter the brushes are driven by three separate belts. It will be noticed that the brushes revolve so that the bristles touching the paper move in the same direction as the paper. The peripheral speed of the bristle tips is, however, 28·3 times as great as the linear speed of the paper.

In view of the weakness of some art papers it is not desirable that the paper should be pulled through this machine solely by means of the power-driven reel-up spindle, even although some assistance may be counted upon from the brushes. It is found necessary to drive all the twelve rollers holding the paper in contact with the brushes. For this purpose power is taken from a countershaft driven by gearing from the main

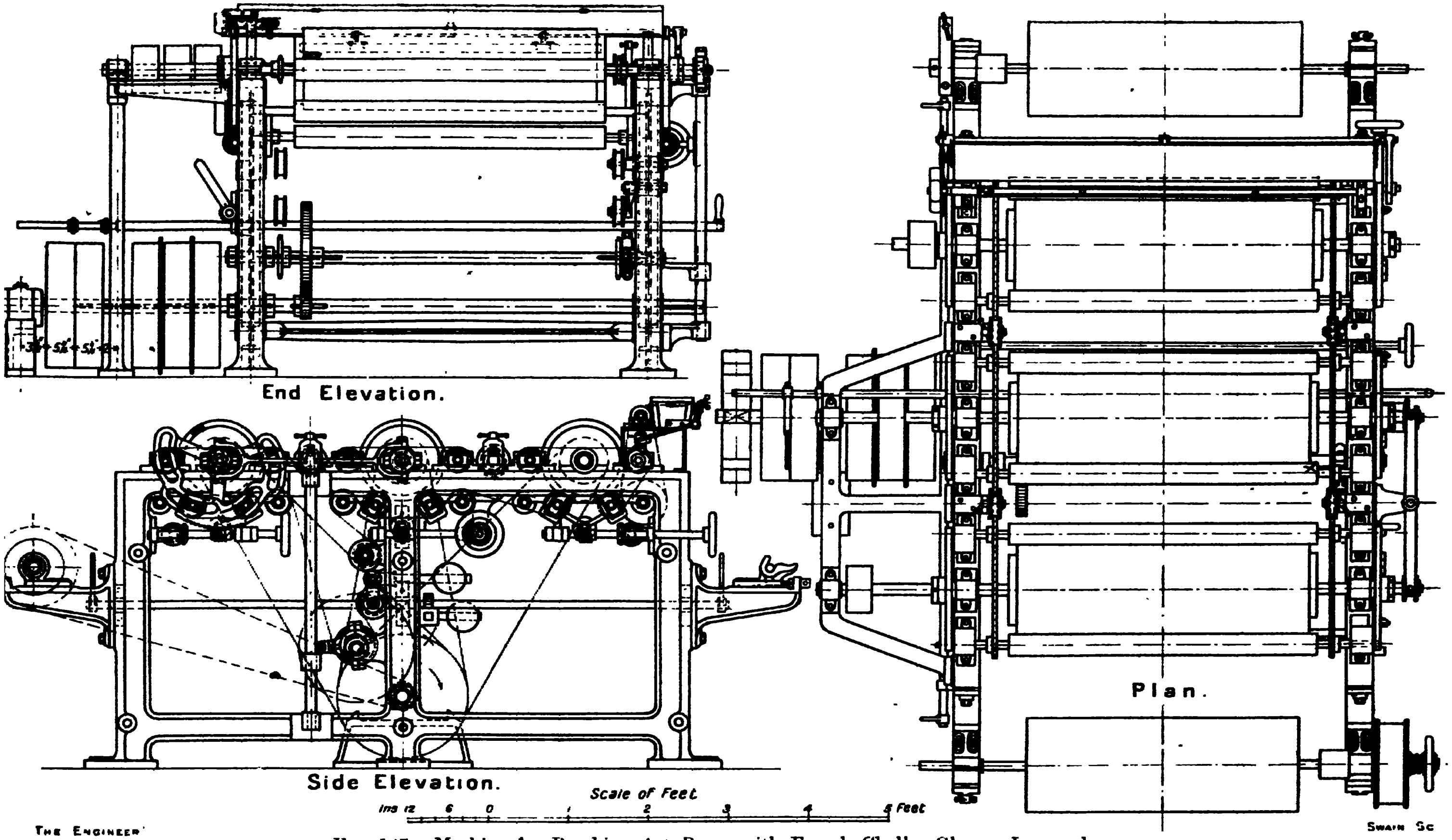


FIG. 127.—Machine for Brushing Art Paper with French Chalk—Glossop Ironworks.

shaft. Each end of the countershaft carries a sprocket wheel. From each of these wheels an endless chain is led round in turn a similar sprocket wheel on the corresponding ends of all the twelve rollers. These two chains have to be kept taut, however the radial positions of the twelve rollers may be adjusted. This is achieved automatically by leading each chain over a small pulley journalled to the end of one arm of a weighted bell-crank lever. Between the brushes, on the top of the frame, there are for each chain two similar pulleys. These can be adjusted by hand and serve to take up any slack in the chain caused by its stretching.

To ensure a uniformity of finish the second and third brushes are provided with a small range reciprocating motion parallel with their shafts. Power for this purpose is taken from the sprocket wheel countershaft through an excentric which is coupled to an arm on a shaft journalled vertically outside the framing. A cross arm fixed to the top of this shaft is engaged with the ends of the two brush spindles through the agency of a race in the well-known way.

The chalk box is made of hard wood sides and ends, the bottom being a sheet of fine gauze. A tin shoot fixed beneath the gauze bottom leads the chalk down and forward on to the paper, the point of discharge being along the line of the paper as it passes over the first of the twelve guide rollers. On one end of this same roller a ratchet wheel is fixed. This actuates through an arm a shaft extending across the front of the chalk box. This shaft is provided at the other end with a suitable spring, and at the mid-point carries a hammer which strikes the chalk box three times in each revolution of the guide roller, so assisting the chalk to pass through the gauze. A small power-driven reciprocating brush engages the chalk as soon as it leaves the lip of the tin shoot.

The material in the brushes is pure wild boar bristle derived from Russian, Indian, and Chinese sources, and carefully blended to give the required stiffness. The driving of the whole machine absorbs some eight horse-power. The main driving belt can be shifted from the fast to the loose pulley at any one of three points. For this purpose a handle, to be pulled, is provided at the front side of the machine beneath the central brush, and a handle, to be turned, at each end close to the winding off and winding on reels.

A very similar paper brushing machine is also being made now by Mather and Platt, Limited. Although the designs are not identical, we need not describe the Manchester made machine, for there is only one point in it which can be regarded as showing an essential difference. We notice that it is the practice of this firm to arrange the first and second roller brushes to be reciprocated instead of the second and third as in the Glossop machine. It is interesting to note that, like the Glossop Ironworks, Mather and Platt, Limited, did not make machines of this class before the outbreak of the war.

CHAPTER XVIII

THE COATING OF PHOTOGRAPHIC PAPER

A SECOND branch of our subject is to be found in the production of photographic printing papers. In itself this is a very important branch and in certain respects is typical of some other branches, such as the production of gum paper. Into the chemistry of photographic papers we do not propose here to enter. It is highly complex and varies greatly from paper to paper. In general sensitised photographic printing paper is paper one side of which has been coated with a salt of silver—usually either the chloride or the bromide—held in suspension in an emulsion of albumen or gelatine. Formerly, and still in the preparation of albumen paper, the paper was first coated with an emulsion of albumen mixed with chloride of ammonia. Thereafter it was floated in a bath of silver nitrate. The nitrate interacting with the chloride produced within the albumen the requisite silver chloride. At present most photographic papers are made with gelatine instead of albumen. In this case the paper is coated straight away with an emulsion of gelatine containing the silver chloride or bromide.

The quality of the paper used is of great importance. The nature of its surface, rough or smooth, may be chosen to suit different tastes, but whatever its surface the paper must chemically be as pure as possible. It should contain no free bleach, and should be unsized, the reason being, of course, that if any foreign chemicals are present in it risk is run of these chemicals reacting with and reducing the silver salts. In particular, there must be no iron or any iron salt in it, for this would at once reduce the silver salts and cause staining or spotting. This is a point of great importance to the engineer supplying the paper coating plant. It means, firstly, that no part of the plant with which the paper comes into direct contact may be made of iron. Wood, copper, ebonite, felt, and other materials must be used instead. Secondly, it is to be noticed that it is next to impossible to guarantee that any paper as received from the mill shall be free from every trace of iron. The merest speck of it will cause a spot on the sensitised paper, and if such spots are frequent a whole reel of paper with its valuable silver coating may be ruined. That specks of iron may very readily be present in the raw paper is obvious, when we recall the fact that the pulp is prepared in beaters, the blades or knives of which are as often of steel as of bronze, and that the wear on these blades is very considerable. The ground-off iron particles go into the pulp and pass into the finished paper.

It is essential, therefore, in order to guarantee freedom from iron stains and spots that the paper before being coated with the sensitised emulsion should be treated with some substance which will impose a neutral " blanket " between the iron particles and the silver salts. The substance adopted, so far as we know, universally, is baryta, that is to say, barium sulphate. This under-coating acts not only as a " blanket " but has the function of improving the surface of the paper, and renders its coating with the sensitised emulsion easier. As barium sulphate also finds employment as a pigment under the name " permanent white," it will be gathered that this preliminary coating has a further value, namely, in making good any deficiency in the bleaching of the paper pulp.[1] It may be added that if the finished paper is to be tinted the colouring matter is put into the baryta coating solution.

There is a great amount of secrecy observed by photographic paper manufacturers regarding the methods followed in their works. But, so far as we can learn, they usually buy their paper already coated with baryta. The baryta coating operation is a very delicate one. Hence comes the reason for its being left to specialists. On the other hand, it can be gathered that the baryta coating process is not a uniform one for all classes of paper, and has to be effected with due regard to the composition of the sensitised emulsion to be borne by the paper. Hence there is a distinct reason why the two processes should be conducted under the one roof.

Into the construction and working of the machines and plant employed for baryta coating we need not go, for the subject is covered by our description of art paper coating appliances. There is no essential difference whatever between the two classes, except in so far as the use of wood, copper, ebonite, &c., instead of iron, is essential in all parts of the baryta plant with which the paper actually comes into contact. As regards the machinery employed to apply the gelatine or other sensitised emulsion, matters are different. While the same care must be taken to avoid contact with iron, the machines used bear little resemblance to those employed for coating art paper. We are in a position to describe and illustrate two typical "gelatine coating machines."

The first is the product of Mather and Platt, Limited, and is illustrated diagrammatically in Fig. 128, and in full detail in the engraving in Plate VI. This machine can take in and coat reels of paper up to 41 in. wide. Referring to the diagram, we have on the right a wooden winding off spindle with an iron centre. From this the web of paper is led round two small and one large wooden draw drums, and from these passes round a pair of wooden guide rollers to a supporting roller of ebonite. Thereafter it is taken over a copper cooling cylinder, off which it is pulled by a travelling felt with a suction box beneath a portion of its length. Leaving the felt it is ready to be dried in a festooning apparatus. At the ebonite supporting roller the paper comes into contact with a coating roller, also of ebonite, which picks up the emulsion from a water-heated bath and conveys it to the surface of the paper. It will be noticed that the side thus coated is the underside of the paper as it leaves the reel. The main driving shaft for the whole machine is situated in line with and just below the highest of the three felt blanket rollers.

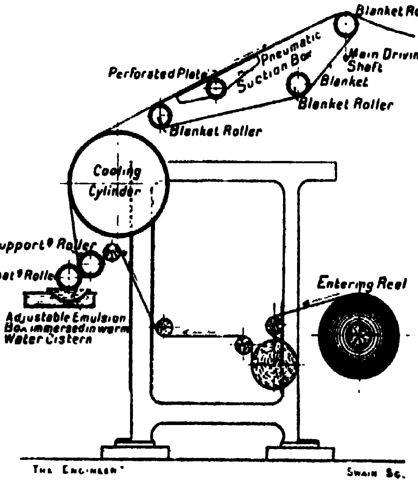


FIG. 128.—Gelatine Coating Machine.

Details regarding the driving and the adjustment of the different parts of the machine will be gathered from the large engraving. The winding off spindle, following the usual practice, is not positively driven. The paper is quite strong enough to withstand the pull necessary to keep the reel rotating. A friction drum brake controlled from the front of the machine is geared to the winding off spindle, and provides a means of checking the speed should the reel tend to overrun the rest of the machine. One of the journals carrying the spindle is permanently fixed to its bracket. The other can be adjusted on its bracket through a short range on each side of its geometrically parallel position. To permit this slight movement to be made without binding the spindle in its bearings the journal bushes into which the spindle is dropped are spherical on the outside. The object of this adjustment is to permit the rectification of the reel should the spindle in use be slightly bent or inaccurately made. There is practically no tendency with a good reel for the spindle to run over to one side or the other. Even if there were, the arrangement adopted for dealing with a reel that has been badly " telescoped " would check this tendency. If a reel is " telescoped " at all seriously, it is necessary to adjust the crosswise position of the spindle progressively as the unwinding proceeds. For this purpose the spindle at the brake drum end is provided with a circular rack which meshes with a pinion on a regulating rod running to the front of the machine. A spring is shown surrounding the end of this rod. This spring increases the friction which has to be overcome before the rod can be turned, and thereby helps to check any tendency of the reel spindle to run to one side or the other.

---

[1] The best photographic printing papers are prepared on paper which has not been bleached by chemicals. In such cases the baryta treatment is particularly necessary in order to get a good colour.

The three wooden draw drums are covered with felt to increase their grip on the paper. The larger drum only is rotated by direct means. It is driven by belt through a coned pulley on its spindle end from a corresponding coned pulley overhead. By regulating the position of the belt on the cones the operator can vary the speed of the drum slightly, and so obtain the requisite " draw " on the paper.

Neither of the two wooden leading rolls round which the paper next passes is driven positively. A similar remark applies to the ebonite supporting roller. The ebonite coating roller, however, is driven by belt and a pair of four stepped pulleys from the end of the main driving shaft. The quantity of emulsion picked up by the coating roller varies with the speed, increasing, we believe, as the speed is raised. The speed adopted and the pressure with which the coating roller is caused to bear against the supporting roller directly affect the thickness of the coating given to the paper. The second wooden guide roller, the supporting roller, and the coating roller are carried in journals on one pair of brackets. The pressure between the two ebonite rollers is adjusted by means of screws bearing against the coating roller journals, which journals are slidable on the brackets.

It is found that the angle at which the paper passes up from the ebonite rollers to the cooling cylinder, and the exact distance covered in this passage, greatly affect the resultant coating. This is clearly to be explained by the influence which these two conditions exercise on the draining back of the emulsion off the paper while it is rising up to the cooling cylinder. Means are therefore provided both for varying the distance and the angle referred to. For this purpose the two brackets carrying the ebonite rolls and the guide roller are mounted so as to be horizontally adjustable on two arms or knees projecting from the main frames of the machine. These knees are themselves adjustable vertically in unison, the adjusting means consisting of a geared hand wheel, a chain drive to a horizontal cross shaft near the floor level, and a pair of vertical screwed shafts connected through mitres with the horizontal shaft. The first of the two wooden guide rollers is mounted in bearings carried on the knees and partakes of the vertical adjustment.

The emulsion bath has to be kept warm, so that the gelatine may not solidify. It is fixed across a water box heated by means of steam flowing through a copper coil within it. The depth of immersion of the coating roller in the emulsion has to be variable to suit requirements. The water box carrying the emulsion bath is therefore provided with means whereby its vertical position can be varied. These same means also permit of the water box and emulsion bath being lowered well away from beneath the coating roller as is convenient when the paper is being led through the machine at the commencement of a run. The adjustment is effected through a hand wheel on the end of a cross shaft which carries a pair of pinions. These pinions mesh with racks formed on the side of two circular bars depending from the bottom of the water box. Guides for these bars are provided in the shape of sleeves which embrace them except for a gap within which the pinions are situated. The sleeves referred to are formed in one with members depending from the brackets carrying the ebonite rollers. Thus the water box and the emulsion trough, while separately adjustable up and down, partake of any horizontal or vertical adjustment of the coating roller brackets. The hand wheel shaft is, of course, journalled to the depending sleeve members. To prevent the weight of the water box rotating the hand wheel shaft backwards, it is provided close to the hand wheel with ratchet gear. With this a pawl pivoted on a second dependence from the coating roller bracket engages.

In passing over the copper cooling cylinder the gelatine of the emulsion is "set." In hot climates ice boxes have to be added to secure this setting, or, alternatively, the whole coating room has to be cooled by refrigeration. Ordinarily, however, the circulation of cold water through the cooling cylinder is sufficient. The water is led into and out of the cylinder through the trunnions. The cylinder is driven by belt. The suction box is a hollow casting, the mouth of which is covered by a perforated plate and the interior of which is in communication with an exhaust fan. The felt blanket passes over the perforated plate. The lowest of the three felt rollers is mounted on screw slides fixed to the ends of the suction box and by it the tension in the blanket may be adjusted. The highest felt roller is carried on a shaft directly above and connected by gearing to the main driving shaft. At one end of the shaft carrying this felt roller we have the coned pulley which drives the large wooden draw drum below, and at the other the belt pulley which drives the cooling cylinder. The third felt roller is adjustable vertically and horizontally to take up slack.

Leaving the topmost point of the felt blanket, the coated paper passes up to a power-driven wooden drum lagged with felt, from which it passes off into a festooning machine, where its drying is completed.

This machine coats paper at the rate of 20 ft. per minute.

CHAPTER XIX

THE COATING OF PHOTOGRAPHIC PAPER (*continued*)

In the machine described in our previous chapter, it is to be observed, the paper is not dipped directly into the sensitised emulsion. The emulsion is lifted from the bath and transferred to the paper by a coating roller. We understand, however, that the machine can readily be altered to the direct dipping method, a system of coating which is favoured by some manufacturers of photographic paper.

A gelatine emulsion coating machine expressly designed to work on the direct dipping system is illustrated in Fig. 129. This machine represents the standardised design of Masson, Scott and Co., Limited, Fulham, S.W. The reel of paper to be coated is mounted on the spindle A at the back of the machine. The right-hand bearing for this spindle can rotate about a vertical axis. The left-hand bearing is carried on a screw slide, so that this end of the spindle can be moved away from or towards the frame standard, so permitting any excentricity of the spindle relatively to the reel to be corrected. This adjustment can be effected from the front of the machine by means of the hand wheel B. A collar and nut or a race—not shown in the engraving—on the left-hand end of the spindle engages with a fork C, which can be moved on a screw carried by the bearing and parallel with the spindle itself. The adjustment of the fork C is effected by means of the hand wheel D, and enables any telescoping of the paper in the reel to be compensated. These two adjustments are required, because it is essential in order to secure an even coating that the paper should pass through the machine at an even tension.

The paper from the reel is led round two brass tensioning rolls E and round a third and larger one F of wood. Coming over the top of the latter, it is passed down and round under a composite wood and brass dipping roller G. In so doing it dips lightly into the sensitised gelatine emulsion carried in a tray H directly beneath the dipping roller. This tray is of copper, silver-plated inside, and provided with a copper jacket, through which steam or hot water is circulated to keep gelatine liquid. The vertical position of the tray can be delicately varied by means of the hand wheel J. The coated paper is next led over a copper cooling drum K, through which cold water is circulated, so that the coating may become "set." The bracket L carries a heated reservoir which supplies the tray H with prepared emulsion. The tensioning roller F, the dipping roller G, and the cooling drum K are driven by a belt, for which a jockey pulley M is provided. The main drive is transmitted through a fast and loose belt pulley on the end of the cooling drum.

The means employed to dry coated sensitised photographic paper do not differ in principle from those used to dry coated art paper. As already indicated, these means consist of a festooning plant. We illustrate in Figs. 130 and 131 two actual examples of such festooning plant for gelatine papers, the first being an example taken from the practice of Masson, Scott and Co., Limited, and the second a plant designed and erected by Mather and Platt, Limited.

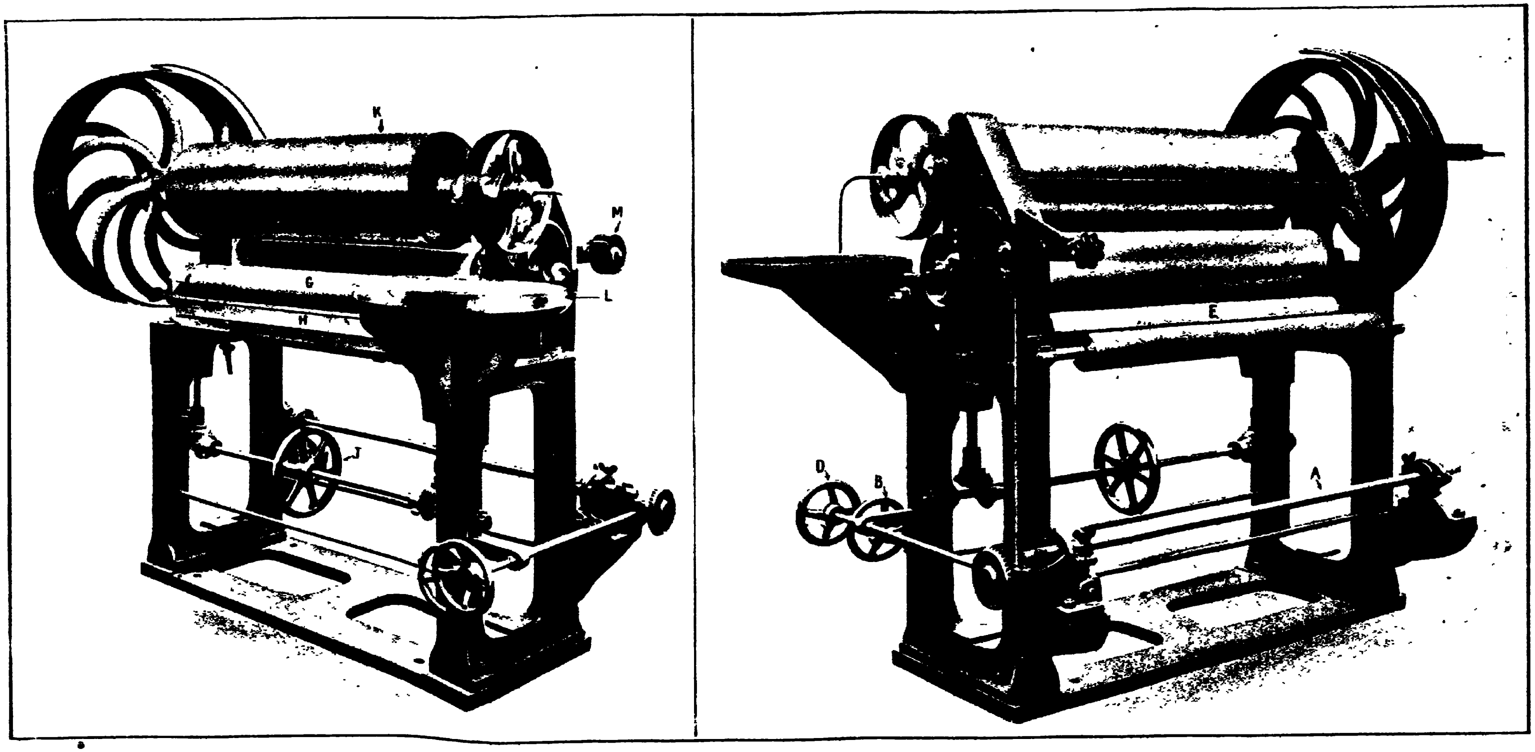


FIG. 129.—Photographic Emulsion Coating Machine—Masson, Scott.

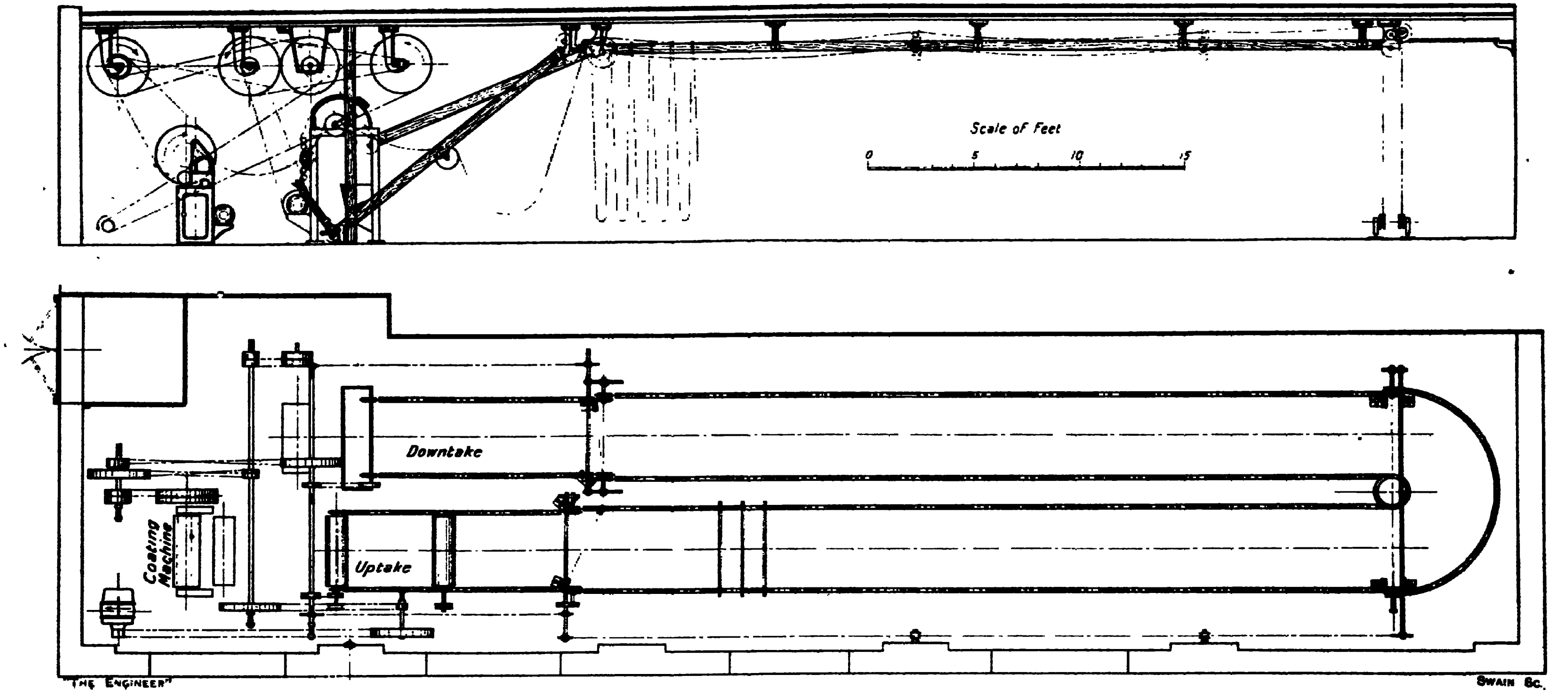
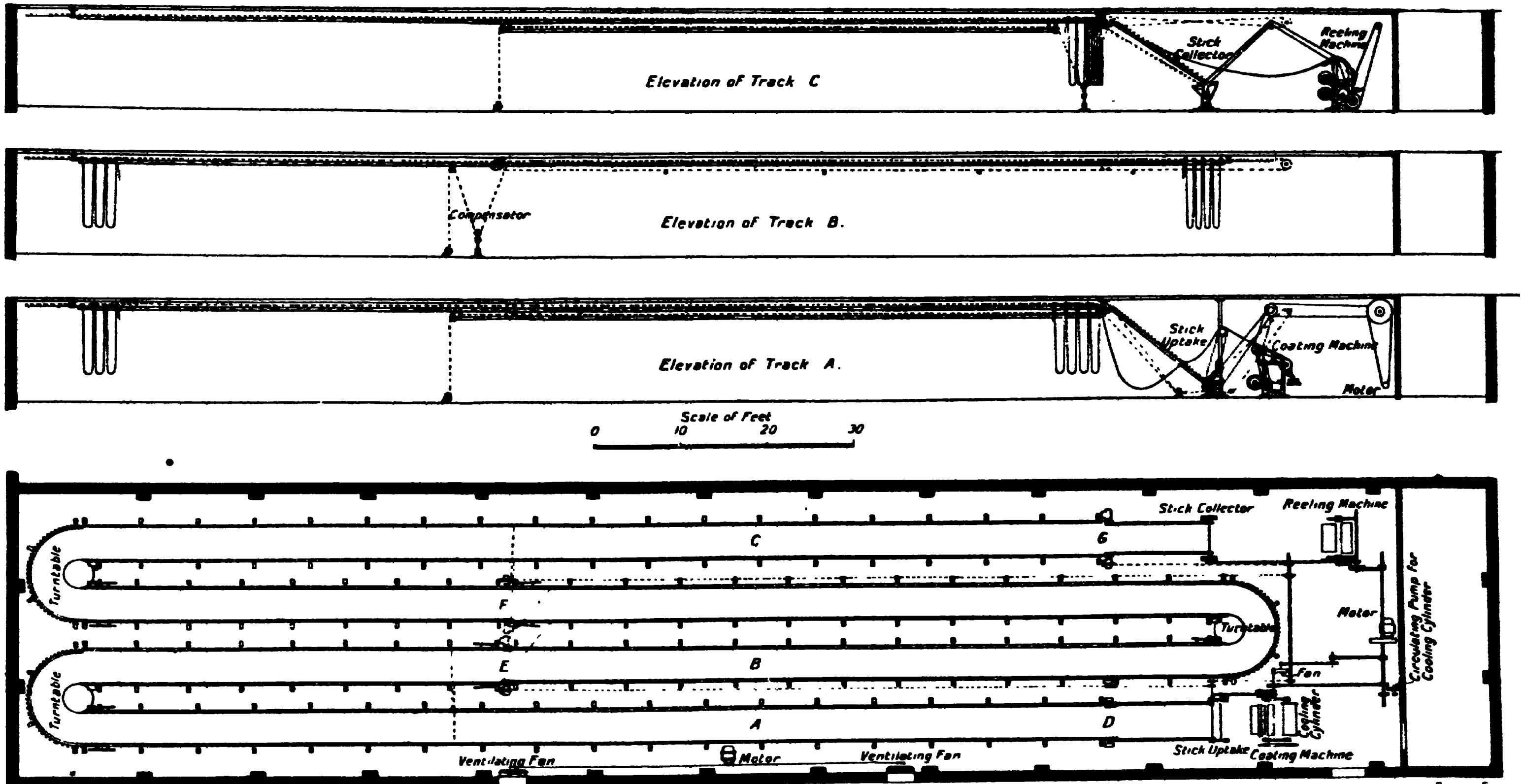


Fig. 130.—Lay-out of a Photographic Paper Coating Plant—Masson, Scott.



"The Engineer"

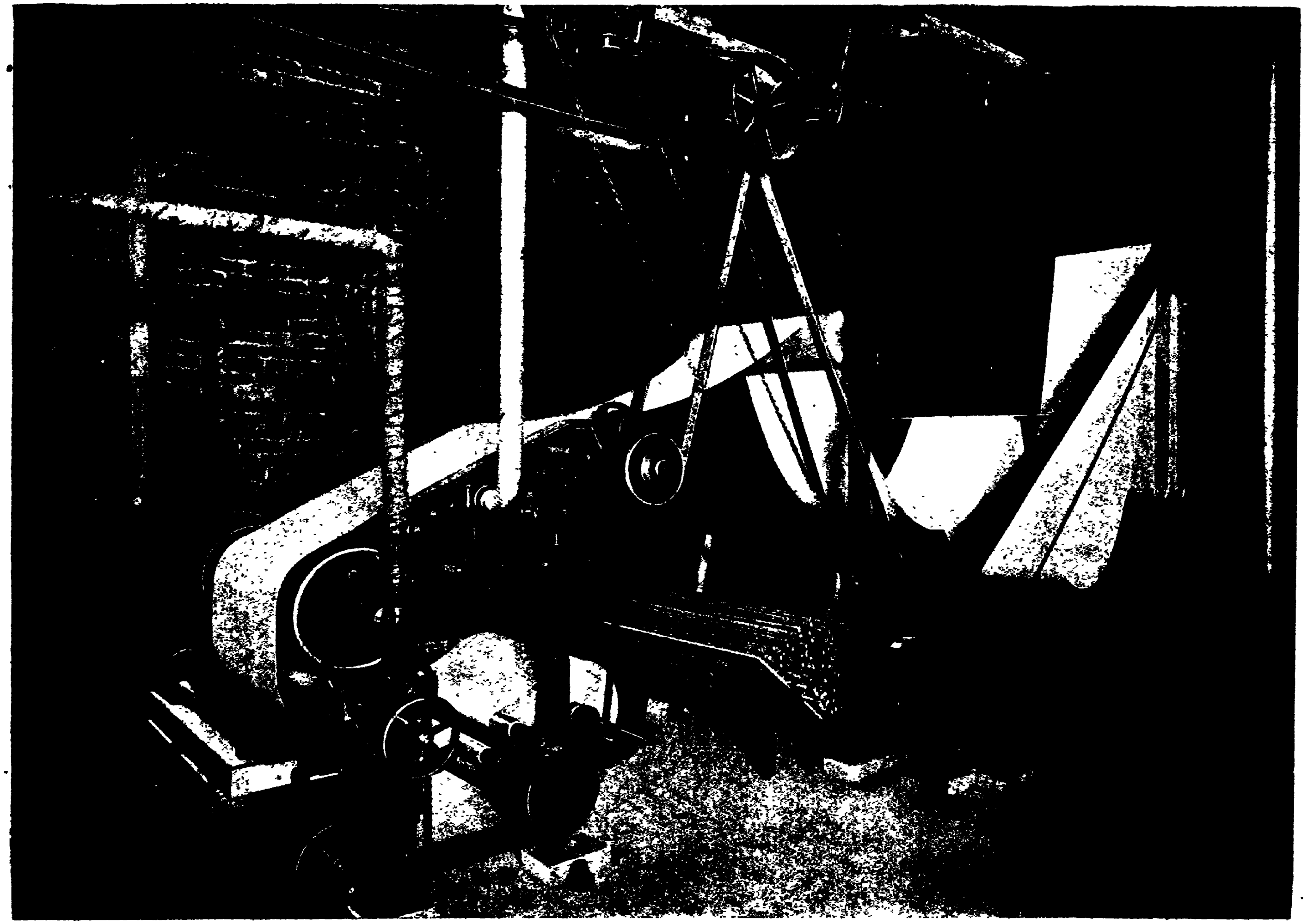
Swain Sc.

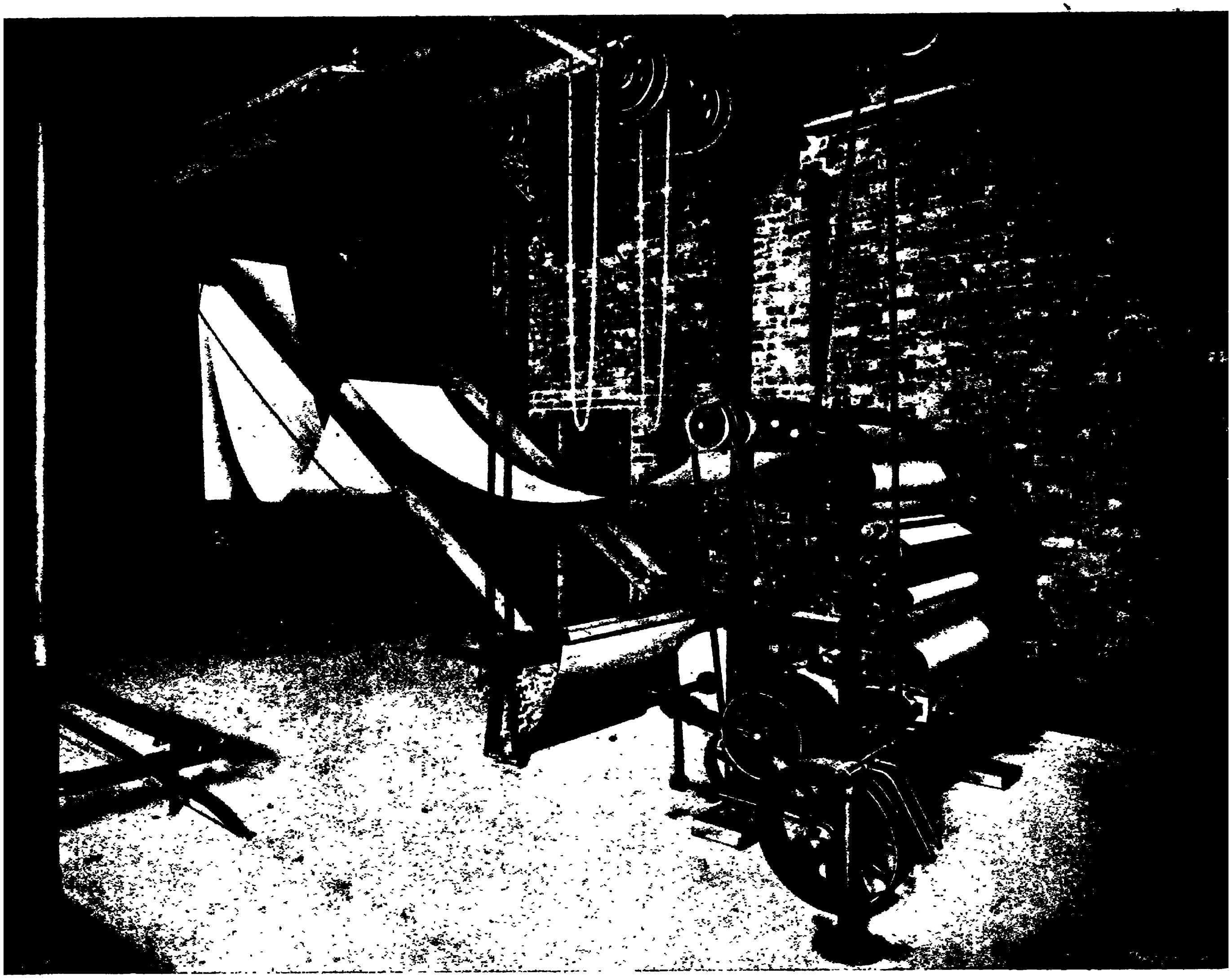
Fig. 131.—Lay-out of a Photographic Paper Coating Plant—Mather and Platt.

PHOTOGRAPHIC PAPER COATING PLANT.

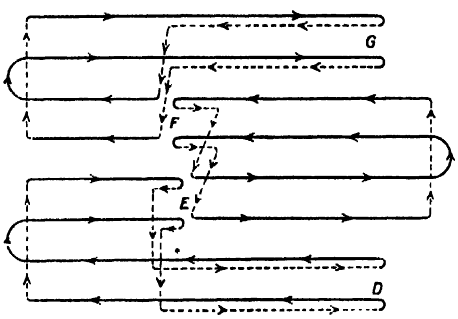
MATHER AND PLATT, LIMITED, MANCHESTER. ENGINEERS.

(*For description see page* 172).





The example by Messrs. Masson, Scott—Fig. 130—is a small installation having a length of 80 ft. or so on the trackway, excluding the uptake, turntable, and downtake. It includes a coating machine of the type illustrated in Fig. 129. There are few points connected with it which need be mentioned after the descriptions of art paper festooning plants given in the previous chapters. It is perhaps worth while calling attention to the fact that the paper between the coating machine and the beginning of the overhead trackway is not in this instance supported on a vacuum felt band arrangement but is carried on two power-driven drums, one of which is fixed between the uptake rails. The uptake chains are driven from their highest point and the downtake chains from their lowest point. The pitch of the sticks on the trackway is 13 in. throughout, so that only one pair of trackway chains is required. These chains are driven from the downtake ends. The outer chain of the turntable is driven in the usual way by a separate countershaft.



"The Engineer" Swain

FIG. 132.—Diagram of Chain Arrangement.

The example by Mather and Platt, Limited—Fig. 131—is considerably bigger than the preceding one. Its trackway is in four lengths, aggregating 500 ft. The coating machine employed is of the type illustrated in our previous chapter. The trackway is in three sections, namely, from D to E, from E to F, and from F to G. The feature of the arrangement lies in the fact that each of these sections makes use of only one chain instead of two, as is usual. The plan followed will be understood from Fig. 132, wherein we have shown in full lines the working portions of the three chains, and in dotted lines the return or idle portions. It may be remarked that a single endless chain per section of trackway need not have a greater length than the combined lengths of two endless chains. The advantage of using a single chain lies chiefly in the attainment of even wear. If two separate chains are used one is led round the pulley of the turntable and is therefore passed from one stretch of the trackway to the next, by being bent through two right angles. The other chain has to be led down to the floor level and up again, and is therefore between the two stretches of trackway bent through four right angles. This chain may be expected to wear more rapidly than the former. By using a single endless chain each link is led in turn round every pulley in the section, and is therefore subjected to an equal wearing action. The division of the trackway into three sections not only permits the pitch and speed of travel of the festoons to be varied from section to section, but also makes it possible to work the trackway with correspondingly reduced stresses in the driving and trackway chains. As a matter of fact, in this installation the pitch and the speed on the second section are equal to the pitch and speed of the third, the break being made simply to provide a third driving point and to avoid the use of an exceptionally long trackway chain. On the first section the sticks are pitched at approximately 17 in. and the speed of the chain is about 1·7 ft. per minute. On the second and third sections the pitch is reduced to 12 in. and the speed to 1·2 ft. per minute. It is possible, we understand, to run all three sections at 17 in. pitch and 1·7 ft. per minute.

The horse-power absorbed by the plant illustrated in Fig. 131 is about 4½, being one horse-power for the coating machine, 2½ for the reeling machine, and one for the trackway drive. As shown in the engraving, the whole plant is operated from a motor-driven countershaft situated at the top end of the room. Two ventilating fans are provided in the wall to conduct the hot vitiated air to the outside. These fans are driven by a six horse-power motor.

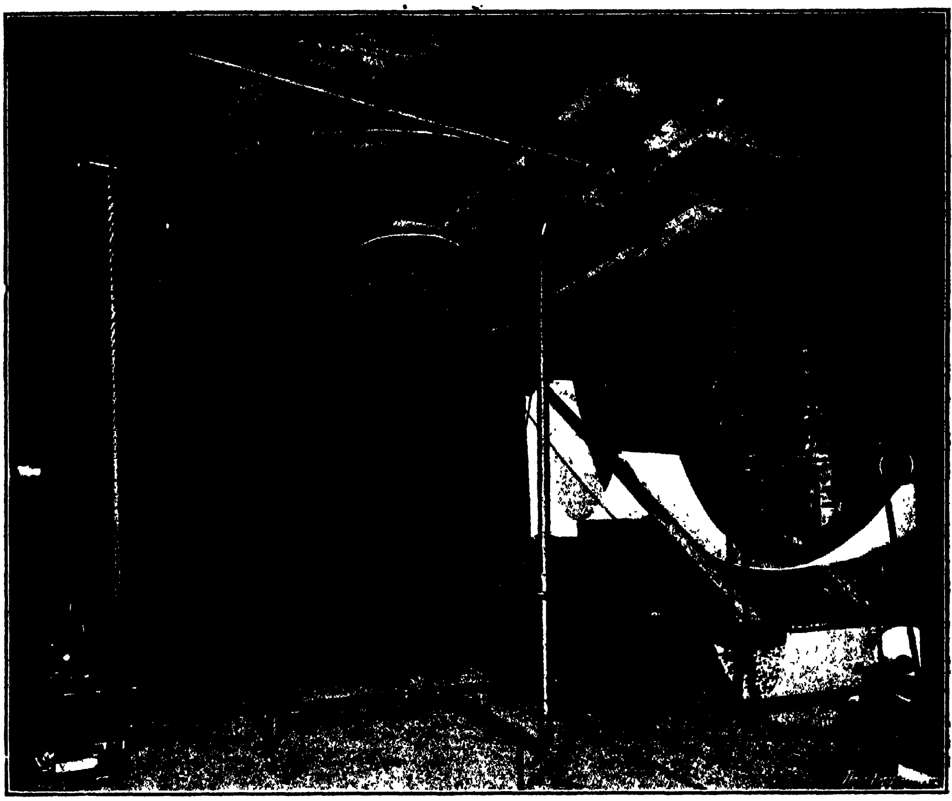


FIG. 133.—Turntable and Downtake—Mather and Platt.

In Fig. 133 we give a view of the plant after erection. This shows the second turntable, the steam pipes below the trackway, and other details. Two other views of the same plant will be found on pages 170 and 171. The first of these shows the coating machine and the uptake end of the trackway. The second illustrates the downtake end of the trackway and the reeling machine.

INDEX

Acme Beater, 42
        with Washing Drum, 43
Air Drying Machine for Tub-sized Papers, 114
Angle-cutting Machine, 132
Art Paper, 144
        Brushing Machine, 158
        Calender, 157
        Coating Machines, 155
        Coating Plants, 146, 151

Backwater Pump, 91
Beating Engines :—
    Acme, 42
    Caldwell and White's, 39
    Hollander, 36
    Hydraulic, 39
    Nash's, 44
    Reed's, 42
    Tower, 40
    Umpherston, 38
Bertram and Happer's Electric Driving System, 74
Bertram and Milne's Power-driven Leading Rolls, 86
Bertrams, Ltd. :
    Acme Beater, 42
    Boiler, Rag, 12
    Boiler, Vomiting, 14
    Chemical Wood Pulp Digester, 137
    Conical Grass Duster, 11
    Expanding Rope Pulley Drive, 70
    Felt Rolls, 96
    Fourdrinier Drive without Clutches, 73
    Fourdrinier Machine at *Daily Telegraph* Mills, 62
    Kneader, 32
    Leading Rolls, Power Driven, 86
    Presse Pâte, 25
    Rag Chopper, 7
    Refiner, 49
    Refiner with Lister's Concentrator, 52
    Rope-driven Fourdrinier, 71
    Spray Cutter, 85
    Steam Connections for Drying Cylinders, 93, 94
    Water Lifter for Drying Cylinders, 94
    Water Trap for Drying Cylinders, 94
    Willow and Duster, 9
Bertrams, Ltd. :—
    Willow, Double Drummed, 11
    Wire Guides, 84
    Wood Pulp Drying Machine, 140
Bertram, James, and Son, Ltd. :—
    Beating Engine, Hollander, 36
    Beating Engine with Hydraulic Plates, 39
    Beating Engine, Umpherston, 38
    Bleach Mixer, 22
    Boiler, vomiting, 13
    Breaking and Washing Engine, 17
    Breaking, Washing and Bleaching Engine, 18
    Cone Breaker, Cornett's, 19
    Driving Gear, White's, 57
    Drying Cylinder Ends, 91
    Drying Cylinder Manhole Covers, 92
    Economiser, Füllner's, 88
    Fourdrinier Machine at Denny, 57
    Happer's Electric Drive, 71
    Mixing and Bleaching Engine, Cornett's, 19
    Rag Cutter, Nuttall's, 7
    Square Cutter, Duplex, 130
    Strainer, "Leith Walk," 100
            White's, 98
    Straw Chopper, 8
    Stuff Catcher, Füllner's, 88
    Water Lifter for Drying Cylinders, 93
Bleaching Engine, Cornett's, 19
Bleaching Towers, 20
Bleach Mixer, 22
Breaking and Washing Engine, 17
Breaking, Washing and Bleaching Engine, 18
Brush Damper, Rotary, 120
Brushing Machine for Art Paper, 158

Caldwell and White's Beater, 39
Calender, Art Paper, 157
        Ten-roll Super, 124
        Three-roll, 120
Calendering, 118
Calenders, 94
Carrongrove Paper Company, 57
Catcher, Stuff, 88
Cellulose, 3
Chemical Wood Pulp, 134, 141
Chemical Wood Pulp Digesters, 137

Chests, Stuff, 87
Chopper, Rag, 7
        Straw, 8
Chopping Machine, Wood, 136
Cloth, Wire, 78
Coating of Art Paper, 144
Coating of Photographic Papers, 162
Coating Machine for Art Paper, 155
Coating Machine for Photographic Paper, 163, 166
Coating Plant for Art Paper, 146, 151
Concentrator, Couper's, 25
        Lister's, 52
Cone Breaker, Cornett's, 19
Conical Grass Duster, 11
Conical Refiner, 48
Cornett's Cone Breaker for Grass and Wood Pulp, 19
Cornett's Mixing and Bleaching Engine, 19
Couch Rolls, 82
Couper Concentrator, 25
Cutter, Duplex Square, 130
        Rag, Nuttall's, 7
        Spray, Greig's, 85
        Square, 131
Cutting Machine, Angular, 132

Daily Telegraph Mills, Machines at, 62
Damper, Rotary Brush, 120
Definition of "Paper," 1
Dickenson Strainer, 108
Digesters, Wood Pulp, 137
        Wood Pulp, Preston's lining for, 138
Disintegrator, Partington, 32
Double Drummed Willow, 11
Driving Gears, Fourdrinier, 69
Driving Gear, Bertram and Happer's Electrical, 74
Driving Gear, Expanding Rope Pulley, 70
        Lumsden's, 72
        Rope, 71
        White's, 57
Driving Gear without Clutches, 73
Drying Cylinder Ends, 91
Drying Cylinder Manhole Covers, 92
Drying Cylinders, Fourdrinier, 91
Drying Cylinders, Steam Connections, 93, 94
        Water Lifters, 93, 94
        Water Trap, 94
Drying Machine for Tub-Sized Papers, 114
Drying Machine for Wood Pulp, 140
Drying Plant for Photographic Paper, 166
Duplex Square Cutter, 130
Duster and Willow for Rags, Jute, etc., 9
Duster, Conical Grass, 11

ECONOMISER, Füllner's, 88
Electrical Drive for Fourdriniers, 74
Endless Felt Bands, 95
Engine Sizing, 109
Esparto Grass, 4
        Vomiting Boiler for, 13, 14
Expanding Rope Pulley Drive for Fourdriniers, 70

FELT Bands, 95
Flat Plate Strainer, 99
Fourdrinier Paper-Making Machine, 56
Fourdrinier Machine, Carrongrove Paper Co.'s, 57
Fourdrinier Machines, *Daily Telegraph*, 62
Fourdrinier Details :—
    Couch Rolls, 82
    Drying Cylinders, 91–94
    Economiser, 88
    Felt Bands, 95
    Felt Rolls, 96
    Leading Rolls, 86
    Pumps, 89–91
    Save-all Tray, 82
    Shaking Arrangement, 80
    Spray Cutter, 85
    Stuff Catcher, 88
    Stuff Chests, 87
    Tube Rolls, 79
    Vacuum Box, 79
    Wet End Arrangement, 82
    Wet End Frames, 81
    Wire Cloth, 78
    Wire Guides, 84
Fourdrinier Drives, 69
Fourdrinier Driving Gear —
    Electrical, 74
    Expanding Rope Pulley, 70
    Lumsden's, 72
    Rope, 71
    White's, 57
    Without Clutches, 73
Füllner Economiser, 88

GELATINE Coating Machine, 163, 166
Glossop Ironworks Co., Ltd. :—
    Brushing Machine for Art Paper, 158
    Kingsland Refiner, 52
    Partington Disintegrator, 32
    Partington Revolving Strainer, 102
    Wood Chopping Machine, 136
Grass, Esparto, 4
Grass Breaking and Washing Engine, 17
Grass, Cone Breaker for, 19
        Conical Duster for, 11

Grass, Vomiting Boilers for, 13, 14
Greig's Spray Cutter, 85

HAND-MADE Paper, 5
Happer Electric Drive, 74
Hinged Flat Plate Strainer, 99
History of Papermaking, 1
Hollander Beating Engines, 36
Hollanders, 16
Hydraulic Bed Plates for Beaters, 39

KINGSLAND Refiner, 52
Kneader, 32
Kollergang, 27

LEADING Rolls, 86
"Leith Walk" Revolving Drum Strainer, 100
Lister's Concentrator, 52
Lumsden and Pearce's Strainer, 99
Lumsden's Drive for Fourdriniers, 72

MANHOLE Covers for Drying Cylinders, 92
Masson, Scott and Co., Ltd.:
  Art Paper Coating Machine, 155
  Art Paper Coating Plant, 151
  Bleaching Towers, 20
  Conical Refiner, 48
  Couper Concentrator, 25
  Drying Plant for Photographic Paper, 166
  Gelatine Coating Machine for Photographic Paper, 166
  Perfect Pulper, 30
  Tower Beater, 40
Mather and Platt, Ltd. :—
  Art Paper Coating Machine, 155
  Art Paper Coating Plant, 146
  Calender for Art Paper, 157
  Drying Plant for Photographic Paper, 166
  Gelatine Coating Machine for Photographic Paper, 163
Mechanical Wood Pulp, 134, 141
Milne, James, and Son, Ltd. :—
  Backwater Pump, 91
  Fourdrinier Wet End Arrangement, 82
  Kollergang, 27
  Lumsden Drive for Fourdriniers, 72
  Nash's Beater, 44
  Read's Beater, 42
  Rotary Brush Damper, 120
  Strainer, Lumsden and Pearce's, 99
  Stuff Chests, 87
  Stuff Pump, 91
  Vacuum Pump, 90, 91
Mixer, Bleach, 22
Mixing and Bleaching Engine, Cornett's, 19

NASH'S Beater, 44
Nuttall's Rag Cutter, 7

OSCILLATING Strainer, White's, 98
Outward Flow Strainer, Wandel, 101

PAPER, Definition of the word, 1
    Manufacture of, by Hand, 5
Paper Manufacture, History of, 1
Paper, Shrinkage of, 69
Partington Disintegrator, 32
Partington Revolving Strainer, 102
Perfect Pulper, 30
Photographic Paper, Coating of, 162
    Drying Plant for, 166
    Gelatine Coating Machine for, 163, 166
Presse Pâte, 25
Preston's Lining for Wood Pulp Digesters, 138
Pulp Strainers, 97
Pulper, Perfect, 30
    Watford, 31
Pulping, 27
Pumps, 89–91
Purifying, 24

RAG Boiler, 12
Rag Chopper, 7
Rag Cutter, 7
Rag Duster, 9
Reed's Beater, 42
Refiner, Conical, 48
    Kingsland, 52
    Milne's, 49
Refining, 46
Revolving Strainers, 100–102
Rope Drives for Fourdriniers, 70, 71
Rotary Brush Damper, 120

SAVE-ALL Tray, 82
Sciennes' Wire Guide, 84
Shaking Arrangements for Fourdriniers, 80
Shrinkage of Paper, 69
Sized Papers, Air Drying Machine for, 114
Sizing of Paper, 109
Sizing Machine, 111
Slitting and Winding Machine, 127
Spray Cutter, Greig's, 85
Square Cutters, 130, 131
Steam Connections for Drying Cylinders, 93, 94
Strainers :—
  Dickenson, 108
  "Leith Walk," 100
  Lumsden and Pearce's, 99
  Partington, 102

Strainers :—
  Vibromotor, 103
  Wandel, 101
  White's, 98
Straw Chopper, 8
Stuff Catcher, Füllner's, 88
Stuff Chests, 87
Stuff Pumps, 91
Super-Calender, Ten-Roll, 124

TOWER Beaters, 40
Tower Bleachers, 20
Tube Rolls, 79
Tub Sizing, 109
  Air Drying Machine for, 114
Tub-Sizing Machine, 111

UMPHERSTON Beater, 38

VACUUM Boxes, 79
Vacuum Pumps, 90, 91
Vibromotor Strainer, 103
Vomiting Boilers, 13, 14

WASHING and Breaking Engines, 17, 18
Water Lifters, 93, 94
Watford Engineering Works, Ltd. :
  Dickenson Strainer, 108
Watford Engineering Works, Ltd :—
  Vibromotor Strainer, 103
  Wandel Strainer, 101
  Watford Pulper, 31
West End Engine Works Co. :—
  Air Drying Machine for Tub-Sized Papers, 114
  Calender, Three-Roll, 120
  Sizing Machine, 111
  Slitting and Winding Machine, 127
  Square Cutter, 131
  Super-Calender, Ten-Roll, 124
Wet End Arrangement, 82
Wet End Frames, 81
White's Driving Gear for Fourdriniers, 57
White's Oscillating Strainer, 98
Willow and Duster, 9
Willow, Double Drummed, 11
Winding Machine, 127
Wire Cloth, Fourdrinier, 78
Wire Guides, 84
Wood Chopping Machine, 136
Wood Pulp, 4, 133
Wood Pulp, Chemical, 134, 141
  Mechanical, 134, 141
  Cone Breaker for, 19
  Digesters, 137
Wood Pulp Digesters, Preston's Lining for, 138
Wood Pulp Drying Machine, 140

WILLIAM BRENDON AND SON, LTD., PRINTERS, PLYMOUTH.

From CONSTABLE'S LIST

The Manufacture of Paper. By R. W. SINDALL, F.C.S. Ex. Cr. 8vo. Illustrated. 8*s.* 6*d.* net. (*The Westminster Series*).

CONTENTS.—Preface. List of Illustrations. Historical Notice. Cellulose and Paper-making Fibres. The Manufacture of Paper from Rags, Esparto and Straw. Wood Pulp and Wood Pulp Papers. Brown Papers and Boards. Special kinds of Paper. Chemicals used in Paper-making. The Process of "Beating." The Dyeing and Colouring of Paper Pulp. Paper Mill Machinery. The Deterioration of Paper. Bibliography. Index.

Wood Pulp. By CHARLES F. CROSS, B.Sc., F.I.C.; E. J. BEVAN, F.I.C., and R. W. SINDALL, F.C.S. Second Edition, revised. 8*s.* 6*d.* net. (*The Westminster Series*).

CONTENTS.—The Structural Elements of Wood. Cellulose as a Chemical. Sources of Supply. Mechanical Wood Pulp. Chemical Wood Pulp. The Bleaching of Wood Pulp. News and Printings Wood Pulp Boards. Utilisation of Wood Waste. Testing of Wood Pulp for Moisture. Wood Pulp and the Textile Industries. Bibliography. Index.

The Manufacture of Leather. By HUGH GARNER BENNETT, M.Sc., F.C.S. Demy 8vo. Illustrated. 18*s.* net.

Glass Manufacture. By WALTER ROSENHAIN, F.R.S. Second Edition, revised. Demy 8vo. Illustrated. 12*s.* 6*d.* net. (*The Westminster Series*).

The Chemistry of the Oil Industries. By J. E. SOUTHCOMBE, M.Sc., F.C.S. Demy 8vo. Illustrated. 8*s.* 6*d.* net.

Linseed Oil and other Seed Oils. By WILLIAM D. ENNIS, M.E. M.Am.Soc.M.E. Medium 8vo. Illustrated. 16*s.* net.

The Production and Treatment of Vegetable Oils. By T. W. CHALMERS, B.Sc., A.M.I.Mech.E. (*The Engineer Series*). Crown 4to. Illustrated. 21*s.* net. Including chapters on the Refining of Oils, Hydrogenation of Oils, Generation of Hydrogen, Soap Making, Recovery and Refining of Glycerine, and the Splitting of Oils.

Cotton Seed Products. By LEEBERT LLOYD LAMBORN. Demy 8vo. Illustrated. 16*s.* net.

A Manual of the Treatment of Cotton Seed for its Products and their Utilisation in the Arts.

Agglutinants and Adhesives of all kinds for all purposes. By H. C. STANDAGE. Demy 8vo. 6*s.* net.

The Nitrocellulose Industry. By EDWARD CHAUNCEY WARDEN, Ph.C., M.A., F.C.S. 2 Vols. Illustrated. 45*s.* net.

A compendium of the history, chemistry, manufacture, commercial application and analysis of nitrates, acetates and xanthates of cellulose as applied to the peaceful arts, with a chapter on gun cotton, smokeless powder and explosive cellulose nitrates.

Please write for our List of TECHNICAL and SCIENTIFIC BOOKS.

CONSTABLE & CO. LTD. 10–12 *Orange St., Leicester Sq., London, W.C.* 2